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The Magazine of Space Exploration

June 1989

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Volume 2, Number 3

After you've seen the Grand Canyon, the only place left to go is Up. Our special section on space tourism begins on page 20. (Cover photo by Tom Useiak.)

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UNITED TECHNOLOGIES PRATT&WHITNEY

FROM THE PUBLISHER

Even folk singers want to go.

Last year John Denver, a full-fledged space buff, offered the Soviets $1,000,000 for a ride into orbit. I guess a million bucks wasn't enough. They set the price at ten times that—more than John was willing to pay, apparently, for his Rocky Mountain (real) high.

Only $10 million? It's probably just a matter of time before some Trump or Getty or Rockefeller shells out the bucks. Relatively speaking, it's not that much money. Aren't there right-fielders who make that in a year?

But what about the rest of us? Ten million is a bit over most people's Visa card limit.

Remember a contest *Omni* magazine ran a couple of years ago? The cover blurb gave us hope that we, too, could win a trip into space! I wanted to believe them. Now, just three years before the scheduled maiden voyage, we find that T.C. Swartz, the man with the big idea, has temporarily given up the mission and sold his company, Space Expeditions.

You can't be down on the guy for giving it a shot. Maybe he blazed a trail—there are a handful of others still trying to make it happen. Someone—maybe even Swartz himself—will get it done, someday.

If it's premature to talk about a space tourist industry, what about NASA reopening its "civilians in space" program? The space agency caught a lot of flak a few years ago for even proposing the idea. But many others thought the Spaceflight Participant Program was—and still is—a way for us all to share in the adventure of space travel.

What do *you* think? We decided to go all out and arrange a phone-in poll. Believe me, arranging a 900 number these days is not easy. I guess 1-900-LUV TALK is more important than the future of space exploration. But we managed it anyway (see page 25).

A friend of mine says that if you really want to create support for the space program, you have to give ordinary folks a ray of hope that they'll get into orbit themselves. To me, a teacher and a journalist in space are good places to start. We *all* know the risks involved. Still, I doubt there'd be any lack of willing participants for the program.

I like the World Space Foundation's attitude. They're selling a T-shirt in the pages of this magazine that screams, "I Want To Go!" I think I'll get one. I want to go, too.

Let us know how you feel about this space tourism business. If we create enough demand, somebody's going to dream up a way to fill the order.

Ever upward,

William Rooney
Publisher

FINAL FRONTIER
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LETTERS

TOM R. GARRETT

Volunteers of America

After reading your article concerning the fight for the space station ("A Fight For Freedom," April 1989), I am going to make a serious proposition to Congress. If they give full funding to the space station, I am willing to spend one year in space (once the station is built and operational) to help NASA evaluate the medical knowledge it would take for a future manned mission to Mars.

Jackie Morris
Alton, Illinois

Memories

I have just finished reading the December issue of your magazine. I thoroughly enjoyed the interview with Bill Anders. It seemed to strike a chord with me, too—I had just turned 10, and was living in Argentina with my parents at the time. The local press, *Time* magazine and the BBC were the only sources of news available. And now, after 20 years, the phrase we seemed to utter interminably that Christmas ("Don't you wish you were up there now?") as we gazed at the Moon came unbidden to my mind. For the first time in years I searched for and dusted off those old and yellow-edged scrapbooks that I never seemed to have the heart to throw out. 1968: Apollo 8—*Time* magazine "Man of the Year." Thank you for reviving those memories.

Rowland Hilder
Randwick, Australia

Strategy for Winning

The nation that wins the space race will be the one that lowers the cost of getting into space fastest. This should be our main goal in space today. Our current fly-off-in-every-direction-at-once policy will lead to defeat.

The high cost of getting into space is a problem common to all space projects, from space stations to Moon bases to economic ventures. Common sense says that our first priority should be solving the common problem.

The high cost of getting into space makes the potential of space seem very distant. For the public, this feeling of distance has drained the excitement out of the space program right when foreign competition and looming budget battles indicate that space needs all of the support it can get.

Back when money grew on trees, we lost our sense of priorities and started putting our Mars missions before our liftoffs, but now that the harvest is over and winter is coming on, it is imperative that we get our priorities in logical sequence.

President Reagan tried to reinvigorate the space program by setting a goal, like the pundits said we needed. His effort failed because he chose the wrong goal. Our main goal in space at this time should be to bring down the cost. It is the only strategy that will win the space race.

James Fennell
Ola, Idaho

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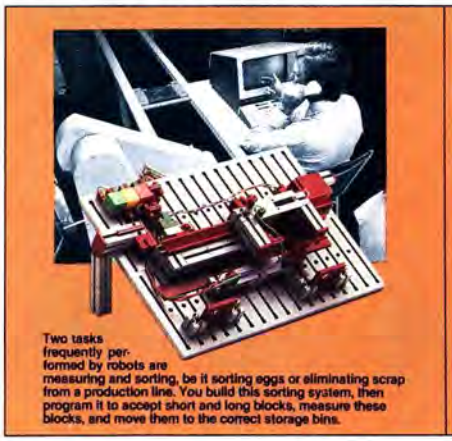

Two tasks frequently performed by robots are measuring and sorting, be it sorting eggs or eliminating scrap from a production line. You build this sorting system, then program it to accept short and long blocks, measure these blocks, and move them to the correct storage bins.

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THE OBSERVATORY

The Vision Thing

We don't ask enough of ourselves.

▼ ▼ ▼

By Congressman Robert S. Walker

"What we need is a vision." Throughout the space community, you hear it said all the time. The idea is that a vision would drive the programs.

But what kind of vision are we talking about? Some define their idea of vision as a human mission to Mars. For others it's a lunar base. Still others point to the space station as a visionary concept. Unfortunately, these are not visions. They are projects. A vision must be much more than a project, even a big project.

"I believe we should go to the Moon," President Kennedy told Congress in 1961. His vision, however, was much larger, something called the New Frontier, which was a different way of thinking about our future. The Apollo program, which took us to the Moon, was but one part of a broader concept of national destiny and interest.

Today, before we conduct great new projects like traveling to Mars or colonizing the Moon, we must think on a visionary level. We need a dream that inspires. President Bush, in his February budget speech to Congress, called space "our destiny." That's a start. But what is really required is to begin to see space as an extension of our national interest, a place where humankind will live, work, colonize and explore, and where our technology can extend our thinking to the farthest reaches of the universe.

Following vision must be real commitment. It is the commitment that is lacking in our political institutions. In the 1960s we were willing to commit 3.6 percent of the federal budget to civilian space activities. That's the equivalent of spending $40 billion a year today. For Fiscal Year 1990, however, the NASA request is $13.3 billion. Yet even so-called visionary proponents of the space program are unwilling to come before Congress and argue for much more than an incremental change in the NASA budget.

"We can't afford it, with deficits and all," they argue. This is nonsense. If we had the political will to invest in the future rather than subsidizing the past, as in Amtrak spending, we could begin to find the resources we need. Likewise, if we had the courage to address big issues like monetary reform, we could save billions of dollars in federal interest costs, money which could then be invested in looking forward.

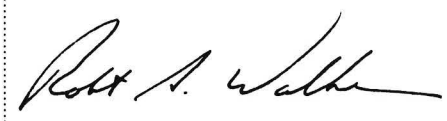
Moreover, we can afford an investment in our space future because the payback will more than finance what the program costs today. Investing $40 billion a year at the beginning of the 1990s can be calculated to return $68.4 billion per year to the Federal treasury by the end of the decade—a business deal that any entrepreneur would welcome. And think what that level of growth could do to help solve the deficit problem.

A commitment to investing at least as much in our space future as the nation was willing to commit in the mid-1960s is a necessary component of any visionary strategy. That level of spending would assure that before the turn of the century this nation would be doing dozens of new science projects in deep space: would occupy a permanently manned space station, would be flying the National Aerospace Place, would have available a heavy lift launch vehicle, would have humans back on the Moon, and would be well on our way toward a manned expedition to Mars. At that point, few would be talking about a lack of vision.

Real vision calls for real risk, because the challenges are real. Vision challenges our courage, our comfort, our spirit and, yes, our financial wherewithal. But if we are not willing to commit ourselves completely to our dreams, they are not likely to happen. Such commitment does not grow from small incremental changes in the status quo. It demands great leaps of faith. In space today, it demands doing at least as much as this nation was willing to do 25 years ago.

In space, the "vision thing" demands visionaries willing to take some risks, because they can see what the future holds.

JANE FLYNN



Robert S. Walker is a Republican Congressman from Pennsylvania, and Vice Chairman of the House Science, Space and Technology Committee.

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NOTES FROM EARTH

ROCK-IT MEN

So what's the big deal, the blushing bass guitarist wants to know? They're "just five guys who can play instruments."

They are "Max Q." The five guys just happen to be NASA astronauts. And the bass player, George "Pinky" Nelson, is a spacewalking veteran of three shuttle flights whose discomfort with star status is obvious.

Max Q plays easy rock 'n' roll—"Whatever's easy enough for us to play," confesses the ever-modest mission specialist, who was on the crew that returned the space shuttle to flight last September. Growing up in southwest Minnesota, Nelson played guitar in a rock band called "The Gnomes," played cello in the high school orchestra and sang in the chorus.

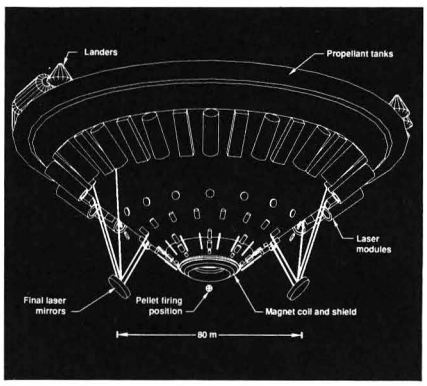
Robert "Hoot" Gibson, who commanded Atlantis' flight last December, is Max Q's lead guitarist; another shuttle captain, Brewster Shaw, plays rhythm guitar. Steve Hawley, scheduled to fly with the Hubble Space Telescope late this year, handles keyboards. Rookie Jim Wetherbee, assigned to a mission aboard Columbia in November, rounds out Max Q on drums.

The band takes its name from the point during the shuttle's ascent, about a minute after liftoff, when aerodynamic pressure is at its peak. Nelson admits that the combo's occasional weekend jam sessions in the garage exert a little aerodynamic pressure of their own ("It gets a little noisy," he says), but the band's praises are sung far and wide. It's not unusual to see Max Q in the spotlight at Pe-Te's, a Cajun barbecue joint near Houston.

"It's fun; it's a good way to pass the time," says Nelson. "Brewster claims it's how he's working through his midlife crisis."

Despite their popularity, at least some people aren't rushing to hear Max Q in concert: "I keep trying to talk my daughters into inviting us to their school to play a dance," Nelson admits. "I haven't succeeded yet."

—Beth Dickey

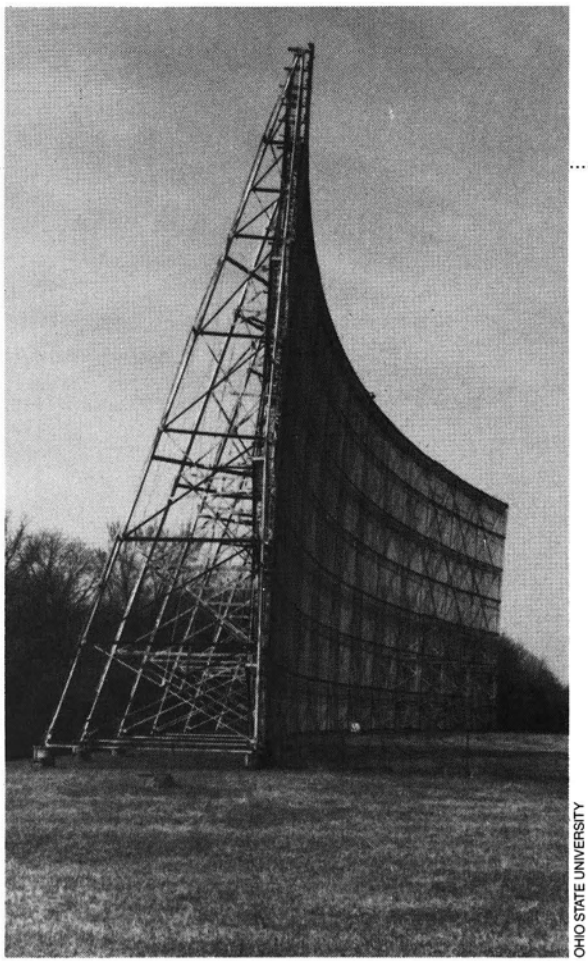


"VISTA" VISION

Forget those dramatic tongues of flame spewing from rockets. Instead, American astronauts may travel to Mars on a trail of tiny thermonuclear bursts.

Researchers from NASA and the Lawrence Livermore National Laboratory in California, one of the nation's centers for designing nuclear weapons, are advocating a spacecraft

Max Q's high five: Brewster, Pinky, Hoot, Jim and Steve.



OHIO STATE UNIVERSITY

The VISTA spacecraft (opposite) may ride mini-nukes to Mars. Ohio State University uses its "Big Ear" (left) in the world's longest-running SETI program.

which would do just that. Their VISTA— "Vehicle for Interplanetary Space Transport Applications"—would be able to fly to Mars and back within 100 days, eliminating most of the hazards that longer space flights pose to astronauts.

VISTA would begin its trip in Earth orbit, ejecting hydrogen pellets weighing 1.75 ounces from its funnel-shaped rear. Powerful onboard lasers would zap each pellet, causing it to explode in a thermonuclear "microexplosion," which would nudge the spacecraft forward. With 30 such blasts each second, VISTA would experience a gentle, steady acceleration, smoother than a typical jetliner takeoff. Because fusion produces much more thrust than the burning of chemical propellants, VISTA could carry enough fuel to reach a speed of 40 kilometers per second. The astronauts then would shut down the engines and coast the rest of the way to Mars.

The working design for VISTA gives the crew spacious living areas on the bow of the 80-meter diameter cone— the large end of the funnel— surrounded by hydrogen tanks to shield them from space radiation. VISTA also would accommodate some type of landing craft to ferry the explorers from Martian orbit to the planet's surface. Current thinking calls for VISTA to spin, creating an artificial gravity environment. "It would be rather exhilarating, riding and viewing the brilliant objects of space from that vantage point," says physicist Charles D. Orth, head of the VISTA project at Livermore labs.

There's one hitch: VISTA couldn't be built with today's technology. Rather, the design team intentionally tried to fashion a craft for the year 2020, when laser-fusion should be a much more mature technology than it is today. The confident designers will submit a final report to NASA this summer. "There's no question that this is the best way to go," Orth says. *—Vincent Kiernan*

STILL LISTENING AFTER ALL THESE YEARS

For decades, Robert Dixon has been taking humanity's eternal quest to hear what the neighbors are saying one step further. He uses Ohio State University's "Big Ear" radio telescope near Delaware, Ohio to learn if we even *have* neighbors.

On line since the 1950s, Big Ear turned to the search for extraterrestrial intelligence (SETI) in 1963, making OSU's program the world's longest-running search for alien messages. Originally, Big Ear concentrated on natural radio signals and, Dixon boasts, the observatory built one of the world's largest catalogs of radio sources.

When federal budget cuts in the early 1970's curtailed that research, Dixon and John Kraus, OSU professor emeritus and founder of the Big Ear, decided in 1973 that they would continue the SETI program on their own, and would make that the primary goal of the telescope. For sixteen years, the effort has depended on private donations, long hours of work put in by a volunteer staff and, more recently, a $15,000 grant from NASA.

Dixon concedes that finding signals from a celestial civilization is a "terribly difficult problem, one that will not be easily solved unless we're terribly lucky." Even after more than a quarter-century, he says that the Big Ear group has "not even scratched the surface."

Dixon admits that Big Ear has never received a verifiable message from an extraterrestrial source. But in the late 1970s the observatory recorded a still unexplained "WOW" signal— so named when a volunteer scribbled "WOW" in a computer printout margin. Dixon says the signal, never heard again, might have been an illegal satellite broadcast on a reserved frequency ...or just may have been a signal from "out there."

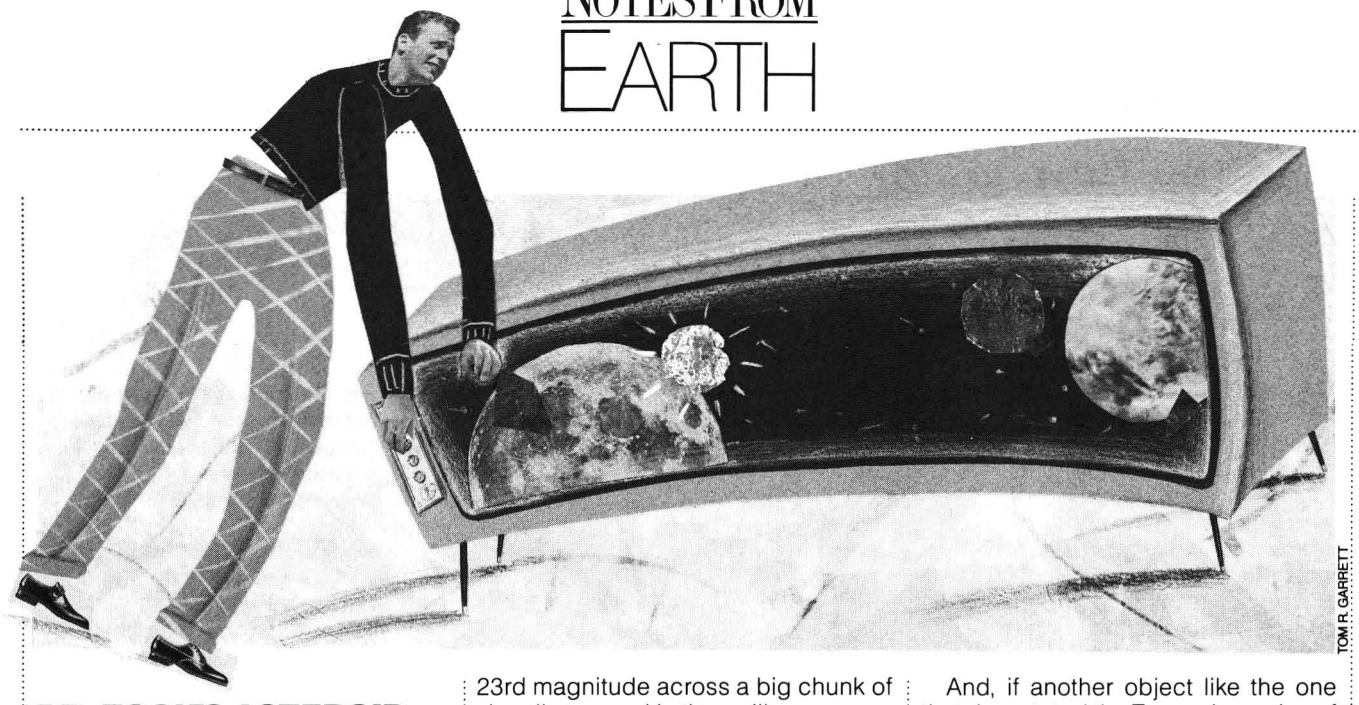
Big Ear listens to the heavens 24 hours per day. As a means of weeding out unwanted signals, the team uses a radio frequency interference dish to catalog spurious radio pollution from man-made sources. With these signals pinpointed, computer controls avoid many false alarms.

Until recently, the radio telescope simply scanned frequencies as the telescope swept across the sky with Earth's rotation. This year, Dixon anticipates that a new software program, which automatically "zooms" in the computer-guided telescope on promising signals, will be available.

Suppose Dixon actually receives a message from millions of light-years away. Could we learn from a civilization that might now be extinct? Dixon thinks so:

"When you read an old book, it doesn't matter that the author has died or even that his entire culture no longer exists." *—Bob D. Gibson*

NOTES FROM EARTH



TOM R. GARRETT

DR. ZOOK'S ASTEROID DETECTOR

Sometimes the sky seems positively full of junk. Even without the man-made clutter in Earth orbit, there are about 10,000 asteroids larger than one kilometer in diameter wandering around the Solar System. And, as for the smaller stuff...just look up on any clear night. You won't have to wait long for a meteor.

You might think this space debris would be pretty easy to spot, but in fact, most asteroids are found by accident; all of them put together wouldn't make a body the size of the Moon. And they're lost in a space large enough to swallow a million Jupiters.

Now a team of researchers led by H.A. Zook of NASA's Johnson Space Center in Houston has come up with a solution to the problem: a "video motion detector." Zook's concept will couple electronic imaging devices with a large, wide-field telescope, enabling him to see everything down to 23rd magnitude across a big chunk of sky, all at once. He then will use a powerful computer to process out the stationary background of stars, leaving behind the "moving junk" (including asteroids, meteors and comets).

A "low-tech" test substituting the eyeballs of a group of researchers for the computer already has successfully proved the concept. Zook expects that his system will be able to detect objects as small as one meter within the orbit of the Moon, and as small as 100 meters halfway out to the Sun.

Zook's effort is more than pure science. Some of the "near-Earth" asteroids are closer to us (in terms of the fuel required to reach them) than the Moon, and they likely will be a prime source of raw material for future space industrialization. Zook's detector may give us a clear idea of how many of these bodies there are, and precisely where they are.

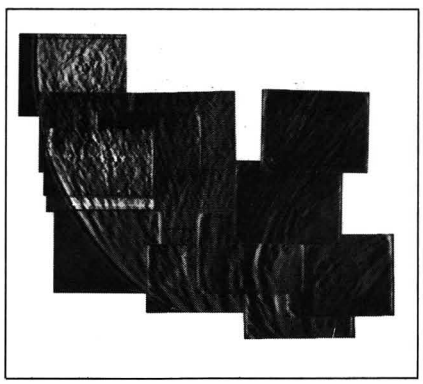
And, if another object like the one that devastated the Tunguska region of Siberia in 1908 comes wandering by, Zook's machine may spot it in time for us to do something beside scream and run for cover.

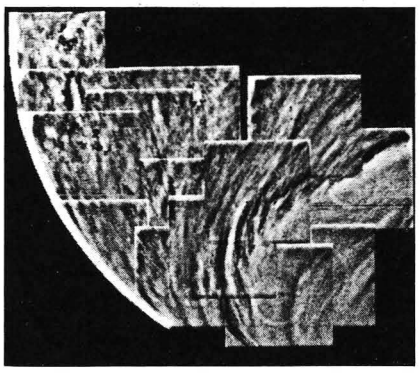
—William Barton and Michael Capobianco

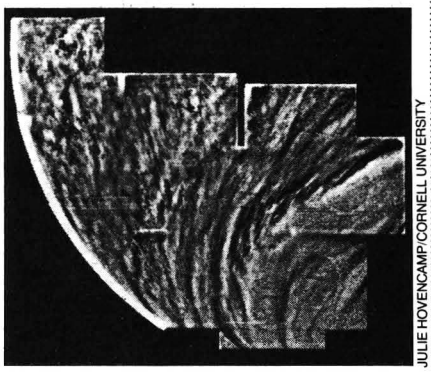
IMAGE IS EVERYTHING

Take a typical photograph of one of your favorite planets or satellites. Then let SPIF, the Spacecraft and Planetary Imaging Facility at Cornell University, start the process that will turn the image into a work of art.

SPIF is one of a few centers that house the thousands of images returned by U.S. planetary spacecraft. Much of the imagery is stored as digitally encoded data; for example, the Voyager 2 spacecraft sends back 640,000 "picture elements" per photo—each with a certain digital code and representing over 200 levels of brightness. By performing various arithmetic operations on each of these dots within the image, SPIF scientists







JULIE HOVENCAMP/CORNELL UNIVERSITY

Easy as 1-2-3: Cornell supercomputers produce a SPIF-fy enhanced image of Venus' cloud patterns.

are able to improve the picture, a process called "image enhancement."

"The images [of the planets and satellites] that are taken by television cameras can see more grey levels than the human eye," explains Peter Thomas, a research scientist at SPIF. "What you have to do is play with a picture, such as changing the contrast, for the human eye to pick out the details."

Thomas explains that SPIF deals with two steps: basic image processing and re-projecting the image into detailed maps. From SPIF, the reproductions often are used by places like NASA's Jet Propulsion Laboratory and the United States Geological Survey to create artificial scenes of planetary bodies. A movie depicting a simulated tour of Mars recently was produced using enhanced spacecraft pictures, with supercomputers storing millions of image data points for such variables as topography, sun angle and planetary brightness and color.

Two scientists from the Soviet Union recently visited Cornell to improve their computer graphics of the Martian satellite Phobos. Seeing the tiny moon in such heightened detail was almost like being there—something the Soviets are only now doing with their unmanned spacecraft, Fobos 2.

—Patricia Barnes-Svarney

NO MORE SHUTTLE SHUFFLE?

"Andy Warhol talked about every person having 15 minutes of fame, and I think I've had more than my share," observes Mike Cahill. A writer/producer for Houston radio station KKBQ, Cahill captured national attention last fall by producing the wacky songs that awakened astronauts on two shuttle missions.

During their first day in orbit last September, Discovery's Mission 26 crew members were jolted from their sleep restraints by a recording of comedian Robin Williams reprising a line from his hit movie, *Good Morning, Vietnam.*

"Goooooood morning, Discovery," Williams belted out. "Rise and shine boys, time to start doing that shuttle shuffle."

On following days the astronauts were serenaded with Cahill's parody of the *Green Acres* TV show theme, and customized versions of the Beach Boys' tunes, "Fun, Fun, Fun" and "I Get Around."

Cahill wrote three more wakeup calls for the secret military flight of Atlantis in December. The lyrics of "Countdown," performed to the *American Bandstand* theme, were made public. But the other two songs were "classified" by the Pentagon, reportedly because they poke fun at secret missions and the astronauts.

After the December flight, NASA considered going back to feeding its shuttle crews a more conventional

canned reveille. Supposedly, the space agency was buried by an avalanche of mail from people who wanted their own songs beamed up to the astronauts. But insiders say the unsolicited submissions weren't the real concern— rumor had it that some NASA officials still were upset about television news clips that highlighted the Discovery astronauts clowning around in space. Also, the Defense Department was steamed that someone had leaked Cahill's secret song lyrics (a parody of the Beatles' "Do You Want to Know a Secret?") to the media during Atlantis' mission.

Jeff Carr, a spokesman for NASA Mission Control, explains that NASA "will always do wakeup calls," but will avoid "elaborate productions. They are not intended to entertain anybody."

That's news to astronaut "Pinky" Nelson, who says that Cahill's recordings for his Discovery flight "were the best wakeup calls I've ever heard. They sure made it a lot of fun to wake up."

—Beth Dickey

TIME IN A BOTTLE

If you were a latter-day Noah, with limited space on an interstellar ark, what would you put aboard? If you could stuff a message into a "bottle" bound for the stars, what would you say?

By the year 2000, the World Timecapsule Fund hopes to have thousands of answers to such questions from around the world. The non-profit organization in Minneapolis plans to create a digitally recorded timecapsule that not only will be displayed (and buried) on Earth, but launched into space.

The mission is designed to inspire educational and cultural institutions to explore and comment on "the meaning of our existence," and "involve the entire world in forming its unique story about the human race," says the Fund's literature.

In the depths of interstellar space, the capsule will endure for millennia, until it's discovered by some alien civilization, or rediscovered by spacefaring humans.

Charles S. Smith, founder and president of the Fund, says the intent of the timecapsule project is similar to that of the records mounted on the Voyager 1 and 2 interplanetary spacecraft. Smith notes, however, that the timecapsule effort is "on a much larger scale," designed to preserve "virtually forever" a vast cross-section of humanity's history, science, religion and art.

A test program was conducted at a Minnesota high school in January, and Smith envisions educational systems as the primary conduit—at least initially. After a semester-long survey of human culture, students will write an essay about the one thing they consider most worthy of preservation. Such responses will form the core of the record.

By 1990, Smith aims to have timecapsule curricula in use throughout Minnesota, and by 1992, nationwide. Then it's a seven-year push to hear from the rest of the world. *—Peter M. Leschak*

SPACEFARERS

Columbus Days

A worldwide celebration of new worlds

▼ ▼ ▼

By Maura J. Mackowski

Pity the poor space program. It goes begging for funding, suffers catastrophic equipment failures and annoying delays, and doesn't always get the greatest press. All to discover and explore new worlds.

Pity poor Christopher Columbus. He begs his way around Europe before Spain sets him up with the *Nina, Pinta* and *Santa Maria*. He sails off in the best that 15th-century technology has to offer, but smithereens his flagship on a reef. His startup settlers are all murdered, and mutiny and intrigue strip him of his title and send him back from his third voyage in chains. He dies penniless after a fourth fruitless trip. All to discover and explore a New World.

Though he probably considered himself a failure, modern society has crowned Genoa's favorite son a hero. Christopher Columbus goes down in the books as the one who began it all, the drive to explore the great unknown out past the blue horizon.

Now they're getting ready to throw a party for the Admiral. 1992 has been named International Space Year (ISY) in honor of the Columbus Quincentennial, which also happens to coincide with the 75th anniversary of the Bolshevik revolution and the 35th anniversary of the first International Geophysical Year that kicked off the Space Age. The United States ISY association is looking for help from a few thousand points of light to make this a real blow-out celebration.

US-ISY hopes to see many and varied space groups sponsor the domestic festivities during the two- to three-year celebration. So far, quite a few have shown interest. The National Space Club and the American Institute of Aeronautics and Astronautics both have indicated their interest in taking part. The World Space Foundation hopes to get its solar sail in flight by '92, and the Radio Amateur Satellite people would like to boost another home-built instrument, or put what they've already launched to some special use.

The Planetary Society is in high gear with a $100,000 essay competition, which will bring twenty winning students from around the world to the United States. And Columbus, Ohio already has staffed a 1992 Commission with the goal of "hooking the program to education and the future."

The idea for a global space celebration was introduced by Senator Spark Matsunaga, a Democrat from Hawaii, and endorsed in 1986 by former President Reagan. Ralph Brescia of NASA's international affairs office is coordinating the space agency's ISY efforts, while Harvey Meyerson, a former aide to Matsunaga, heads the US-ISY Association, a NASA subcontractor.

NASA was asked to lead an interagency effort, domestically and internationally, to organize the event. "Unlike 1957," says Brescia, "we have a number of space agencies that didn't exist then in other countries. We now have an opportunity to bring them together."

Particular emphasis will be given to projects that unite the globe and share the largesse of the space nations with their less developed neighbors. Perhaps the biggest ISY project, Brescia says, is Mission to Planet Earth. "We're trying to study Earth as a planet, a system," he explains. "This approach allows the space-flying nations to participate because of their remote sensing capabilities. It also allows us to involve the developing countries using their [ground-based] data."

TRACY TURNER

When NASA asked other space agencies for their participation and ideas, the result was SAFISY, the Space Agency Forum on International Space Year, which in turn sets up a panel of experts to implement various programs.

For example, an Earth sciences subcommittee hosted by the British is working on several ideas, including a project to study deforestation, an "Encyclopedia of the Earth" that Brescia says would "bring knowledge of climate and geography about any point on Earth to the PC level for any student," and a remote sensing atlas of the world, which would be particularly useful for developing nations.

The French are spearheading an education and applications subcommittee to educate the general public and developing countries in space technology. "The whole idea is to open it up to people who may not see themselves working in space," says Brescia.

In the United States, NASA is working with other government agencies and the Smithsonian Institution. "We're planning the first international showing of IMAX films [shot in space], hoping to encourage ISY activities," says Meyerson. Meanwhile, WQED in Pittsburgh, the station that produced the *Planet Earth* television series, is creating a documentary on the ISY project. US-ISY hopes to translate the program into several languages for use around the world.

Meyerson stresses that activities need not be elaborate nor expensive, but that they should involve and educate as much of the public as possible. He's heartened by the response to date and predicts that more groups will turn out to honor Columbus and his successors in the discovery of new worlds.

We think so, too. Watch this space. □

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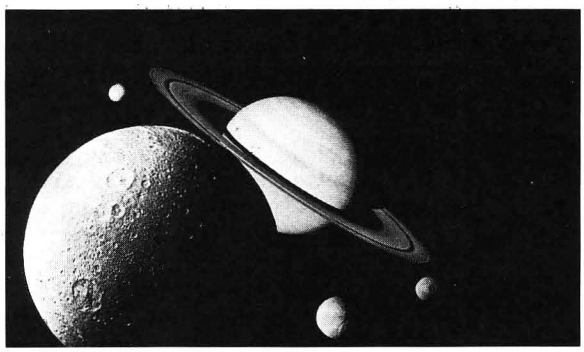

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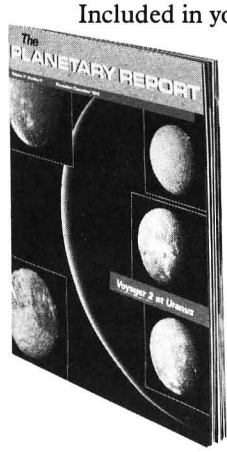

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Co-founders of The Planetary Society: Bruce Murray, Professor of Planetary Sciences, California Institute of Technology (seated left); Carl Sagan, Director, Laboratory for Planetary Studies, Cornell University (seated right); Louis Friedman, Executive Director (standing).

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THE PRIVATE VECTOR

The Price of Liberty

Pacific American Launch Systems (PALS), a start-up rocket company in Menlo Park, California, finally has landed a fee-paying contract. Worth $400,000, the contract allows the U.S. Army Strategic Defense Command to evaluate the first stage of the PALS' Liberty launch vehicle, a two-stage booster that may eventually be able to deliver about 400 pounds to low-Earth orbit.

According to PALS President Gary Hudson, the contract has financed "a number of unspectacular but important tests" such as fuel tank pressurization and rocket motor ignition. A test firing of the first stage at Edwards Air Force Base also is planned. "It's a lot like paying to take a car for a test ride," says Hudson.

While some of the test results were anticipated, Hudson notes that others "turned out better than expected." The original contract was scheduled to last three months starting last August, but the program was extended another six months. PALS did not request additional funding from the Army for the extension.

Development and construction of the Liberty booster is financed solely through private funding; the Army contract is for testing only. As a bonus, test results will provide PALS with data it needs to sell Liberty launch vehicles to prospective customers.

—Robert G. Nichols

Wanna Buy a Space Robot?

Wanted: private financing to build a $30 million water tank to train space station astronauts.

That's just one of the advertisements NASA could run to help shore up its budget for the 1990 fiscal year. Through a new set of commercial initiatives, NASA hopes the private sector will add $208 million to the agency's purse by financing new facilities and hardware. The projects, including an advanced robot to service space station Freedom, are all things NASA says it needs—but the White House says it can't afford.

Of course, the private sector is interested in making a profit. So potential financiers of the training tank to be built at NASA's Johnson Space Center in Houston might be able to lease the facility to the offshore drilling industry in Texas. NASA's space station chief James Odom says it's not reaching too far to expect that drillers could use the tank to instruct technicians how to sink or repair oil wells.

Realistically, however, NASA is presumed to be the prime customer for all the projects. At a hearing last winter on NASA's budget request, Democratic Senator Al Gore called the private financing initiatives "gimmicks," and asked NASA head James Fletcher rhetorically if he *really* expected "R.J.R. Nabisco" to consider buying the space agency a station robot.

Fletcher admitted that industry will be hard pressed to finance technologies like the robot (called the Flight Telerobotic Servicer), which involve substantial investment in cutting-edge research and development. Other projects targeted for private financing are: a facility for building advanced solid rocket motors for the shuttle (an estimated $60 million in NASA's 1990 budget); a space station payload processing facility at Kennedy Space Center ($43 million); an observational instruments lab at the Jet Propulsion Laboratory ($14 million); enhancements to the shuttle which could help it remain in orbit nearly a month ($27 million); and a space station docking module ($4 million).

—Melinda Gipson

PACIFIC AMERICAN LAUNCH SYSTEMS

Pacific American's proposed Liberty launcher: "Like paying to take a car for a test ride."

... Or Some NASA Real Estate?

Even NASA's field centers may wind up on the block in the rush toward "privatization."

A science policy paper issued in early January by the National Academy of Sciences and the National Academy of Engineering recommends a major study of the benefits of turning over some or all of NASA's field installations to the private sector. The paper suggests that NASA's centers could offer more attractive salaries and have better, more modern facilities by affiliating with a university or an aerospace company. "[Privatizing the centers] would get around a number of handicaps that

the government has, such as salary schedules...and bureaucratic functioning," says Guyford Stever, chairman of the academies' space policy committee.

NASA Associate Deputy Administrator Noel Hinners notes that commercializing the field centers isn't a new idea, but that not much was done with it until about six months ago, when NASA's Ames Research Center in California did a preliminary analysis.

Partly due to its Silicon Valley location, Ames was finding that it was "not getting the best fresh-out-of-college talent," Hinners explains. Ann Bradley, NASA's director of personnel, estimates that industry outbids the space agency by about $5,000 per year for the brightest college graduates.

NASA is proceeding with a more in-depth study which should be completed by next summer, or even sooner "if the [Bush] administration pushes," says Hinners. He acknowledges that the Cal Tech-operated Jet Propulsion Laboratory (cited by the academies as a model for privatization) seems to "be able to attract and retain a higher degree of talent" than some other NASA laboratories, but points out that JPL was well established before it became part of NASA in the early 1960s.

Jerry Grey, director of science and technology policy for the American Institute of Aeronautics and Astronautics, is dubious about privatization. NASA still would be required to finance the centers, says Grey, and he doubts that it would greatly streamline operations. Grey thinks that private industry would benefit financially from the operating fee, but doesn't believe that the firms "would get anything they don't already have," from a technical standpoint. *—Douglas Isbell*

Ariane Supersavers

Arianespace, the private corporation that markets and launches Europe's Ariane boosters, has come up with a new scheme to help reduce the cost of sending small payloads into orbit.

The organization's latest "budget" program is aimed at the mini-satellite market. For a token cost, several small payloads can be carried into low Earth orbit on a structure that fits beneath Ariane's primary satellite cargo.

According to Edward Weinrich, engineering director for Arianespace, there are several restrictions. Payloads can't weigh more than 40 kilograms each, and the overall mass of the small satellites can't exceed 200kg. They also have to be as compact as possible—about 40 centimeters square. Finally, the tag-along satellites must not interfere with the primary payloads.

As part of this program—so new that it doesn't yet have a formal name—six small satellites will be carried into orbit along with the French SPOT Earth observation satellite later this year. Most are designed to demonstrate new spaceflight communications technology: one of the satellites, built for Webster State University, will carry an Earth observation color video system to gather images for student research.

Fees totaling about $1 million cover the cost of integrating the satellites onto the payload structure. Weinrich cautions that this is still a new program, so a "real pricing policy" has yet to be formulated. If successful, however, it could become a regular and economical means of delivering "mini-payloads" to orbit.

—Robert G. Nichols

THE ULTIMATE VACATION

Is there hope for the space tourist? ■ *By Jerome Richard*

The new office of Space Expeditions, Inc. is on the seventy-fourth floor of the Columbia Center. The view over Seattle's hills is magnificent, but there is something sad about it, too. The company was organized to arrange space trips for private citizens. The brochure said: "Imagine seeing the Earth, its curvature, continents, oceans, countries, lights, even atmospheric conditions, all from an entirely different view." But for now, this is as far off the ground as Space Expeditions can get. ■ The idea was to develop a fleet of private spaceships that would take as many as 20 passengers at a time on a five-to eight-orbit trip around the Earth. The target date for the inaugural flight was 1992, the 500th anniversary of Columbus' voyage to the New World. ■ Space Expeditions' president, T.C. Swartz, also founded and later sold Society Expeditions, a unique travel organization that used its own ships to take well-heeled tourists to exotic places, accompanied by informed guides who lectured on the local culture. As Swartz puts it, the purpose was to provide "experiences that people remember." Project Space Voyage was

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Fodor's 89

The Fodor Guide to Space

Eugene Fodor has lived a life others can only envy. Now in his eighties, he created the well-known series of travel guides bearing his name in 1936. The Fodor Guides now number 90, and the list is still growing. Travelers throughout the world carry tattered copies of the books in search of historic sights, restaurants and places to stay. In 1978, Fodor was elected to the American Society of Travel Agents World Congress Hall of Fame, the first travel editor to be so honored.

So where would the ultimate traveler go if he could only take one more trip? "My choice would be a press trip onboard one of the forthcoming space shuttle series," Fodor says, adding that the idea has "a special timeliness" at this stage of his life.

"Lest it appear as some mindless fantasy," says Fodor, "I have given it a great deal of thought in the past." He even once went so far as to discuss it with Christopher Kraft, the former director of NASA's manned spaceflight program.

"I assume it would be an immensely rewarding and unprecedented experience," continues Mr. Travel himself, "and a fitting and fulfilling assignment for an exiting travel editor."

Fodor may have to pull rank and elbow some of his own employees out of the way if tickets to Earth orbit become available. Michael Spring, editorial director in charge of the more than 300 writers who contribute to the Fodor Guides, says that "When Fodor's is ready to cover travel in space, my bags are packed."

He isn't the only one in the travel industry with such dreams. Steve Noveck of Official Airline Guides, the bibles of air travel, says "It will be exciting when OAG adds space travel to our coverage," and promises that all aspects of commercial tourism in orbit would be covered in the guide books, including flight schedules and articles about tour packages, travel agent tips and industry news.

Adventure travel excursions have mushroomed in the last decade, and Sobek Expeditions has been on the cutting edge of the trend. In the company's *Book of 1000 Adventures,* author David Roberts writes that "once-tricky voyages have become safe and routine as the wrinkles in potentially hazardous exploits have been ironed out." But one of the difficulties of commercial space travel could be the fear factor, which might pose a public relations problem for any space vacation industry. Duffy Myers, a travel PR expert with the Orlando-based firm RY&P, is undaunted by the challenge.

"We are anxious to represent the pioneers in commercial space travel," says Myers. "Because we are based in Florida, we think marketing space travel to civilians would be exciting and productive. The public relations ramifications are numerous."

Then, of course, there are all the magazines that could be geared to space vacationers and even business travelers. Connie Goldstein, editor of *Corporate Meetings and Incentives,* a journal for people who plan business meetings, is already thinking ahead.

"Our readers are always looking for new and unique destinations for their groups," she says. "Just as it took teleconferencing many years to be accepted, I think meetings in space will take a generation before they are accepted as a unique, distraction-free and productive way to conduct business."

Anita Cotter, travel editor for *Glamour* magazine, has no doubt that her readers "would be especially interested in commercial space travel—they are traditionally at the forefront of developments in all areas." Cotter even goes so far as to offer a prediction: "I would suspect a *Glamour* reader would be the first woman tourist in space."

— *W. Lynn Seldon, Jr.*

to have had a similar format, with astronauts and space experts riding along on the weekly orbital trips to provide commentary.

Announcement of the project four years ago resulted in more than 10,000 inquiries; 186 people put up $5,000 deposits held in escrow to reserve their places on the orbital tours. Azeezaly Jaffer, a NASA public information officer at the time, declared that "Space tourism is a realistic concept."

Realistic, maybe, but not realized. Last January, those people who had booked passage on Project Space Voyage received a letter from Swartz, saying, "Since we cannot give you an exact target launching date, and since it is so far behind our original schedule, we no longer feel comfortable in having your deposit in escrow." Subscribers were given three options: withdrawing their deposit, letting it stay in escrow indefinitely, or applying it to Swartz's new venture, Private Jet Expeditions.

The new company will use a Boeing 727 refurbished with deluxe accommodations to take tourists to "destinations of extraordinary interest." Those who apply their $5,000 Project Space Voyage deposits to a Private Jet Expeditions trip within a year receive a $2,000 discount. While waiting to see the Earth from orbit, they can visit Katmandu. The new company, which shares office space with Space Expeditions, is awaiting regulatory approval.

Like others who had considered the idea of space tourism before him, Swartz's original plan was to develop a passenger module for the cargo bay of NASA's space shuttle. When the space agency's director, James Beggs, decided in 1985 that tourists would not be allowed onboard the shuttle, the company, then a part of Society Expeditions, decided to contract for the design and building of its own spaceship, although Swartz still anticipated using government launch facilities, probably at Vandenberg Air Force Base in California.

The tragedy of Challenger did little to discourage space-minded citizens from wanting to go into orbit—Space Expeditions had very few cancellations—but it did discourage financial backers. Swartz's rough budget for the project had anticipated $5-10 million to complete systems engineering work, $40 million to construct a completely operable scale model, and $150-200 million for the craft itself. Each flight would cost about $240,000 for fuel and the amortized cost of the vehicle, and would earn $1 million in revenue from fares alone—20 passengers at $50,000 apiece. There was also the possibility of carrying commercial cargo.

But Swartz's cost estimates have since gone way up. By the time a man-rated spaceship was tested and outfitted with redundant safety systems, he now figures, it would cost more like $2 billion. Even with a fleet of three ships operating weekly, it would take almost twenty years to turn a profit.

As Swartz wrote in his letter to depositors: "The amounts needed for space exploration must be supported by government infrastructure, as the financial numbers from a purely commercial aspect become unrealistic without this kind of infrastructure assistance." He points as an example to the government's paying development costs for the military aircraft that eventually became the Boeing 707 passenger jet.

But restrictions on NASA's budget, and the weight of the federal budget deficit,

SPACE EXPEDITIONS

make government help unlikely, especially since there seems to be no burning official interest in getting civilians into space. In January, NASA announced indefinite postponement of its "Teacher in Space" and "Journalist in Space" programs, saying only that the possibility of reviving them will be considered "on an annual basis."

At first Swartz sought private funds through venture capital groups and looked into a public stock offering. His letter reports that, "Things started to look promising in the financial community, until the stock market crash of October 1987." After that there was little taste for risk left among possible financiers. Swartz continued to explore possibilities, but concluded by the end of last year that it was time to return the deposits.

"If the Challenger hadn't blown up," he says, "we'd be right on schedule." Swartz hasn't abandoned hope. In fact, he says emphatically: "We're going to do it eventually." But eventually now looks like the first decade of the next century.

Alan Ladwig, who once managed NASA's "citizens in space" program and is now Director of Special Projects in the agency's Office of Exploration, believes the Spaceflight Participant Program, as it's officially called, will be revived. While some members of Congress question the idea of private citizens in space, he points out that the public still accepts the risk. However, that is not the same thing as opening NASA shuttles to tourists.

"NASA is not in the personal transportation business," Ladwig says. "That's the role of the private sector." He is optimistic, however, that such an industry will develop: "Anyone who thinks that's not going to happen is short-sighted." Ladwig points out that *The New York Times* once claimed that Robert Goddard's idea of going to the Moon was fantasy.

WOLFGANG KAEHLER

The staff of Space Expeditions, Inc. hoped their Project Space Voyage would be ferrying passengers to orbit by 1992. Now, says company founder T.C. Swartz, it may be the first decade of the next century before space tourism gets off the ground.

A market forecast study of space travel and tourism prospects for the period from 1990 to 2000, conducted last year by Space Propulsion & Power, Inc. of Menlo Park, California, seems to support that optimistic view. Incorporating several previous studies and relying on two key assumptions—that "low-cost ($100 per pound delivered to orbit) space transportation is technically feasible" and that "high-

volume demand (thousands of passengers per year) will materialize to support the investment in the technology"—the company foresees revenue of as much as $1 billion by 1998, plus additional income from auxiliary activities (ground hotels, commercial payloads, etc.).

The study identified two technologies that show promise of achieving low-cost space transport: Electromagnetic launch (EML) for bulk materials, and a single-stage, Vertical-Take-off-and-Vertical-Landing reusable passenger shuttle. The latter was Space Expeditions' vehicle of choice for ferrying tourists to orbit, even though it's still a controversial idea among aerospace engineers. Any technology that helps to bring down the cost of reaching orbit—including the hypersonic spaceplanes expected to be flying early in the next century—could make space transportation market-driven instead of dependent on government funds.

Swartz, who distributed copies of the market study along with his letters announcing indefinite postponement of Project Space Voyage, says that if Space Propulsion develops the hardware, Space Expeditions will provide the passengers.

Tom Rogers of the Space Phoenix Program agrees that "the fundamental problem in the civil space area is cost," and he doesn't expect much help from the government. "People will not allow government assets to be used to take millionaires into space." Space Phoenix also wants to open space to the general public, but is doubtful that a spaceship to accomplish that purpose can be designed and fabricated at a reasonable cost. Instead, the group has its eyes on a passenger-size vessel that NASA already takes into space and then jettisons—the shuttle's external fuel tank, or ET.

An ET is 27.6 feet in diameter and 153 feet long—about the size of a Boeing 747. Designed to carry the shuttle's liquid oxygen and hydrogen fuel, the tank is made of 30 tons of strengthened aluminum, and costs about $30 million to manufacture. Given a $5,000 per pound lifting cost, each ET represents about a third of a billion dollars. When the shuttle reaches orbit, the tank is released to break up and burn in the atmosphere. So far, nearly 30 ETs have gone down that way.

When NASA announced in 1987 a new policy of giving away discarded tanks to potential commercial users, several groups stepped forward to accept the offer, including some 700 students from Hilldale Elementary School in Muskogee, Oklahoma, who wanted the tanks so they could one day live in space (NASA turned down the students' proposal, citing concern over their ability to pay the engineering costs, but presented Hilldale with an award for educational achievement instead).

Space Phoenix is made up of three organizations: The University Corporation for Atmospheric Research (UCAR), a non-profit consortium of 58 scientific institutions and research universities, The UCAR Foundation, and the External Tanks Corporation (ETCO), a for-profit company created to manage the financing, development and operation of ETs for both scientific and commercial use.

NASA scientists confirm that ETs could be put into near-Earth orbit without appreciable loss of payload capacity or increased launch cost, and NASA and UCAR officials have signed an agreement that permits

While You're Waiting..

Okay. Unless you have a few billion dollars to finance your own launch vehicle, it's just *possible* that you were born too early to experience the wonders of space travel for yourself. But don't despair—the picture for would-be astronauts isn't totally bleak. You can still get a feel for the real thing, right here on the home planet.

Many museums and visitor centers across the country are now offering "space-on-Earth" experiences in the form of camps, training simulators and the like. We've put together a list of these programs, both existing and planned. One note: Although many of them started out as programs for children, most also offer space experiences for adults.

Space Camp and Space Academy, Huntsville, Alabama

The granddaddy of all space-on-Earth experiences, this is the program that has the copyright on the terms "Space Camp" and "Space Academy" (really). About 23,000 space campers are expected to pass through Huntsville's program this year alone. For adults, that includes three days (in the fall only) of astronaut "training": Participants get to "space walk" in a Manned Maneuvering Unit simulator; experience 3g's in a centrifuge; and become disoriented by the multi-axis simulator, which mimics navigation in space by rotating 360 degrees in every direction.

A happy camper at the Pacific Rim Academy

OREGON MUSEUM OF SCIENCE AND INDUSTRY

Everyone also takes part in a simulated shuttle launch. Some group members are assigned to mission control; others make up the shuttle crew (the assignments are reversed the following day). And just to add to the sense of reality, campers are housed in a "Space Habitat"—dorms that look like NASA's proposed space station.

Space Camp sessions for children are even more involved, ranging from five- to ten-day "missions," some of which offer an hour of college credit. Since the camp is affiliated with the Alabama Space and Rocket Center and is near NASA's Marshall Space Flight Center, campers also get to tour and use those facilities. The camp is open year-round, and has programs for children from grade 4 on up. Space Camp is, however, rather pricey: The three-day adult program costs $450, which includes room and board. Programs for the kids range from $425 to $800, depending on the length and type of program.

Space Camp also offers a five-day Teacher Space Orientation (for graduate credit) in the summer; the cost is $595 complete. For more information on all programs, call 1-800-63SPACE.

U.S. Space Camp, Titusville, Florida

A joint venture between the original Space Camp in Huntsville and the Mercury Seven Foundation. NASA's Ken-

the Space Phoenix Program to begin its first phase of operations—the suborbital use of the External Tank as a platform for scientific and commercial experiments.

Initial plans are to outfit the ET's "intertank" section, located between the hydrogen and oxygen tanks, to house these experiments. But eventually the entire tank would be converted to warehouse, laboratory and even habitat space. Tom Rogers, chairman of the board of ETCO, has even thought ahead to using ET's for space tourism. Already, a professor at the Imperial College in London is working on a design for installing windows and otherwise modifying the orbiting vessel. The problems, which include eliminating the toxic fumes left behind by the fuel, are enormous.

Rogers perceives a booming market for space travel. High volume—10,000 people a year—would make

nedy Space Center is nearby, and bus tours are available. The camp's programs and prices are basically the same as Huntsville's. Call 1-800-63SPACE for more information.

Patrick Baudry Space Camp, Blajnac, France

French "spationaute" Patrick Baudry spent several years developing this camp, which is set to open this summer. Kids 10 through 17 can attend the week-long sessions. Activities include lessons on the technology of space, training on 17 different simulators and a "launch, flight and landing" of the Hermes mini-shuttle. The camp, located near Cannes, costs about $560 per week, including room and board. For more information, write to Espace Development, Space Camp Patrick Baudry, Residence Thales, Parc Industriel Aeroportuaire, 31700 Blajnac, France.

Challenger Center for Space Science Education

The year: 2061. The place: a space station, spinning its way toward a rendezvous with Halley's Comet. The mission: To send a probe to the comet's coma. This is the scenario of the Challenger Center for Space Science Education—a network of facilities across the country that promotes science in a "fun" way. The Challenger Center was founded as a memorial to the crew of shuttle mission 51-L.

The prototype center is now open in Houston, in the Museum of Natural Science. It includes two rooms—"Mission Control" and the "space station." Although the Challenger Center doesn't have Space Camp's high-tech simulators, the rooms look and feel pretty realistic, says Douglas King, president. For instance, the spacecraft has computers, an isolation chamber and a glove box. The emphasis of the two-hour simulation is not on spaceflight itself, but on what you do once you're there, says King.

Any museum or school district can apply to become a Challenger center; so far, four sites have been approved, and eight are pending approval—the center hopes one day to have 50 sites. A flagship center is now under construction near L'Enfant Plaza in Washington, D.C. Called the Space Life Station, it will simulate life aboard a space station, and will have room for 75 people at a time for simulations lasting up to a week.

Though the only "mission" running currently is the Halley rendezvous, eventually the centers will offer a variety of options, some short enough to be included as part of a museum tour, others lasting several days. The next planned mission is a return trip to the Moon.

Many of the Challenger Center's participants will be children. However, the Houston prototype also offers evening and weekend classes for families and adults. The cost ranges from $5 to $20, depending on the session. For more information, contact the Challenger Center for Space Science Education at 800-533-6310, or write to PO Box 90077, Washington, DC 20090.

Space Center Houston, Johnson Space Center, Texas

NASA's Johnson Space Center has grand plans for revamping its visitors center, and has even hired Walt Disney Imagineering to design a new 40-acre facility. So far, plans call for a two-level

the costs practical, and he says that 10,000 "is only 1% of the people who want to go. Polls show that people want to take a trip to space." Still, Rogers doesn't think it will happen until the first decade of the next century—the same timetable envisioned by T.C. Swartz.

The Space Trust Corporation is taking a different approach. The Florida-based outfit hopes to sign up 2.5 million members at $50 each to participate in a random selection to determine passengers for space travel. The idea is to construct, using private money, a 55-seat Passenger Accommodation Compartment that would fill the payload bay of a space shuttle orbiter for a 24-hour, 17-orbit trip. The compartment would have large side and overhead windows, somewhat like a tour bus.

The money raised through memberships and corporate sponsorships would be enough to ensure that the lottery winners would not have to pay any additional fares. Besides entry in the drawing, members will receive newsletters for their $50. Since Space Expeditions already has demonstrated that there are a substantial number of people willing to pay $50,000 for such a trip, a lively market could develop for scalping winning tickets.

"The people who go will have the most fun they've ever had."

NASA has not endorsed the program, but it hasn't rejected it out of hand, either. In an August 1988 letter to D. Jordan Taylor, president of Space Trust, H. Hollister Cantus, then NASA's Associate Administrator for External Relations, was even mildly encouraging: "NASA appreciates the efforts of The Space Trust Corporation and is supportive of the ideals and objectives of your non-profit organization....We look forward to exploring the ways in which our two organizations might work together to further our common interests." Taylor has hopes that the first passenger launch could take place as soon as three years from now.

But a lot of people can't wait. Last year John Denver tried to buy a ride on a Soviet spaceship for $1 million, and in November an Oklahoma farmer and banker named Elmer Graham made the newspapers by offering the Russians a million dollars worth of grain for a trip to space. Graham, an intrepid 73-year-old who once hunted polar bears in Alaska, says he wants to go simply because he thinks he would enjoy it. "When they went to the Moon," he says, "I couldn't take my eyes off the television."

Graham hasn't heard from the Russians yet, which he thinks is a good sign, but Arthur M. Dula, president of the Space Commerce Corporation in Houston, which markets Soviet space services, is doubtful. He says the true cost of training someone and putting him into space is more like $12 to 15

domed building to house live demonstrations, film and video exhibits, along with live coverage of NASA missions. One area, called the "Feel of Space," will have hands-on exhibits. Visitors will get to "dock" a shuttle to a space station, use a remote mechanical hand, walk through a shuttle crew compartment and participate in demonstrations of eating, drinking and cooking in space.

Another live demonstration area will have a multi-axis trainer to nauseate selected participants, and an air-bearing floor to give others the illusion of weightlessness. True to the Hollywood roots of the Disney folks, the new visitors center also will have tram tours of Johnson Space Center, with what promoters advertise as "the opportunity to catch a glimpse of the astronauts in their daily working environment." Space Center Houston is scheduled to open in the spring of 1991. Admission will probably be about $5 a person.

NASA's Ames Research Center also is considering developing some type of air and space center, in cooperation with its hometown of Mountain View, California, outside San Francisco. Plans are in the preliminary/very tentative stages.

Space Camp, Space World, Yawata, Japan

Sometime in the spring of 1990 an official Huntsville-licensed space camp—complete with dorms and simulators—will open on the island of Kyushu in Japan. The camp will actually be part of a Space World theme park built by the Nippon Steel corporation. Attractions will include a museum, rides and, of course, a space theatre. Nippon Steel eventually plans to build three such theme parks in Japan.

Future Astronaut Training Program, Kansas Cosmosphere and Space Center, Hutchinson, Kansas

This for-kids-only program sticks to its future astronaut theme: A typical five-day agenda includes space survival training (how to go to the bathroom in space, what to eat), workouts on a Link flight simulator and a Manned Maneuvering Unit simulator, and a simulated shuttle launch. The Cosmosphere's program is open to children in grades 7 through 9, and costs from $450 to $525, depending on the level of the program (room and board included). Sessions run from June to August for Level I; October through November for the more advanced Level II. For more information, write to the Future Astronaut Training Program, Kansas Cosmosphere and Space Center, 1100 North Plum Street, Hutchinson, Kansas 67501, or phone 316-662-2305.

Pacific Rim Spaceflight Academy, Oregon Museum of Science and Industry, Portland, Oregon

Spend a peaceful summer—send your kids to this academy and they'll learn how to survive in the desert, how to fly a plane and how to manage for themselves in weightlessness. The academy incorporates the principles of flight and spaceflight into its five-day programs (the kids don't actually fly a plane, but they do get a ride in a Cessna, and children in the advanced program get a ride in a helicopter).

The academy also has an underwater training facility to demonstrate moving in zero-gravity, as well as other

million. (In fact, John Denver backed off when Glavkosmos, the Soviet space marketing agency, informed him that the going rate for his joy ride would be $10 million). That, counters T.C. Swartz, is because the Soyuz vehicle only seats three people. Even if you could reduce the crew down to one cosmonaut, that leaves only two seats left to sell.

Meanwhile, the American Experimental Spaceflight Association in Carteret, New Jersey recently issued "An Invitation To Fly To The Edge Of Space." For $25 a year, members get a bi-monthly newsletter and a chance to participate in several space-related activities. One is a "Flight To The Edge of Space," probably onboard a chartered Concorde. AESA hopes this will take place in 1992. It would involve a flight "into the stratosphere upwards of 20 kilometers," where "One may see the deep hues of the edge of space and the curve of Earth near the horizon." Other activities may include attending shuttle launches and astronaut training, and short zero-gravity flights.

AESA, according to president Paul M. Geyer, was "founded by guys who went to space camp together." Their major activities so far appear to lie somewhere between a dream and a plan, but the group does have a coveted Get Away Special reservation for a small shuttle payload. NASA stopped issuing these reservations at 652; AESA holds reservation # 650. AESA doesn't expect their number to come up until the late '90s, but one idea is to include their membership roster as part of the payload. If you can't go yourself, perhaps your name can orbit the Earth for you. Meanwhile, AESA offers "Your Trip Into Space" presentations for schools and civic groups.

So there is a space race still. All these groups, and probably half a dozen more now welding together bits of metal and wire in their garages, hope to be the first to open space to the public, and that's just in this country. When Project Space Voyage was announced, Senator Jake Garn, who flew on the shuttle, said "The people who go will have the most fun they've ever had in their lives." Here's to you, Elmer Graham. We hope you make it.

Meanwhile, Space Expeditions is contemplating selling meteorites—a reminder that while we can't go to space yet, a little bit of space still comes to us. □

Jerome Richards is a Seattle-based writer whose articles have appeared, appropriately, in both Science Digest *and* Travel & Leisure.

The following organizations have taken an active interest in promoting future space tourism:

American Experimental Spaceflight Association, 1501 Roosevelt Ave., F-1, Carteret, NJ 07008; phone: (201) 541-6786.

Space Expeditions, Inc. (Private Jet Expeditions), 701 Fifth Ave., suite 7450, Seattle, WA 98104; phone: (206) 386-5801.

Space Phoenix Program, 1877 Broadway, suite 405, Boulder, CO 80302; phone: (303) 440-8070.

Space Propulsion & Power, Inc., P.O. Box E, Menlo Park, CA 94026; phone: (415) 494-2025.

Space Trust Corp., P.O. Box 511, Cape Canaveral, FL 32920; Send $50 and self-addressed, stamped envelope for membership. No phone calls.

gadgets to simulate the feel of spaceflight. Kids ages 9 to 18 are eligible to attend the sessions (groups are based on ages), which run from June through August. The cost is $510 for OMSI members; $530 for non-members. For more information, call 503-222-2828, or write to the Pacific Rim Spaceflight Academy, Oregon Museum of Science and Industry, 4015 SW Canyon Road, Portland, Oregon 97221.

Shuttle Camp, Space Center, Alamogordo, New Mexico

For five days, kids in grades 3 through 9 get to build and launch model rockets, participate in underwater zero-g simulations, eat space food and mess with actual space hardware (including shuttle tiles and space helmets). Shuttle Campers also take field trips to nearby White Sands Missile Range (sometimes during an actual rocket launch) and Holloman Air Force Base. The program has both day camp and overnight sessions. Prices range from $60 to $250, depending on session length. For more information, call 800-545-4021, or write to Shuttle Camp, Space Center, Alamogordo, New Mexico 88311.

Aerospace Camp, Cradle of Aviation Museum, Garden City, New York

Because this is an air and space museum, activities focus on aviation as well as space. Kids in grades 6 to 8 build and launch model rockets, try on space suits and attempt to "repair" satellites, and take behind-the-scenes field trips to New York's Kennedy Airport and Grumman Aerospace Corporation. The prototype of a larger future program, the camp costs $125 for four days (sessions are four hours a day). For more information, call 516-222-1190 or write to Aerospace Camp, Cradle of Aviation Museum, Museum Lane, Mitchel Field, Garden City, New York 11530.

Michigan Space Camp, Jackson, Michigan

This day camp has one session for kids in kindergarten through the 4th grade, and another for grades 5 through 8. Everyone gets to build model rockets from scratch, visit a planetarium and take a field trip to an airport. Eighth graders have the option of sleeping over on Friday for a night of star-gazing. The camp costs $75 for one week. For more information, write attn. Glen Swanson, 2111 Emmons Rd., Jackson, Michigan 49201; or call 517-787-4425.

Tour of the Universe, CN Tower, Toronto

More an amusement park ride than a real space center, this futuristic adventure through a 21st-century airport culminates in a harrowing ride around Jupiter in Europe's Hermes "mini-shuttle." The shuttle is actually a flight simulator; its movements are computer-coordinated to match the action on a film projected on the shuttle's windscreen. Allow about an hour for the entire adventure: 10 minutes for the ride, and 50 minutes of waiting to get there. The waiting line is an adventure in itself: You have to pass through "security" and be inoculated against space viruses. Tour of the Universe costs $11.95 (Canadian) for adults, $4 for kids 12 and under. A Tour of the Universe is slated to open in Japan in 1990; so far there are no definite plans to open one in the United States.

—Devera Pine

ARTIFICIAL GRAVITY

Our intrepid reporter takes The Rotating Room and The Robocot for a spin.

BY C. J. HOUTCHENS

I'm already apprehensive, but the list clinches it. I'm in the belly, as it were, of the Ashton Graybiel Spatial Orientation Lab at Brandeis University in Waltham, Massachusetts, moments away from a spin in the rotating room. I'm wondering if eating lunch was such a great idea, when I see the list tacked to the bulletin board: a neatly penned parchment poster of "Ye Olde Synonyms"—all the dubiously hilarious ways of saying what I'm now certain I'll do in the next ten minutes. Upchuck. Retch. Ride the rail. Ralph. Talk into the big white telephone. Worship the porcelain god. And—how's this for euphemism—*laugh* at the ground.

What the hell am I doing here? Good question. I'm about to experience, firsthand, the effects—and side effects—of "artificial gravity." The idea of rotating a spacecraft to counteract the effects of weightlessness has been around ever since physicists and sci-fiers began noodling with Newton's laws and considering the physical implications of traveling beyond Earth's gravity. We've seen it in Hermann Oberth's pioneering projections from the 1920s and in Stanley Kubrick's languidly waltzing *2001* space station.

On Earth, stomach-lurching carnival rides like "The Barrel" and "Gravitron" spin so quickly that when the floor drops out beneath them, shrieking teenagers are pinned in place to the wall by centrifugal force. Eureka! Artificial gravity.

Until recently, we haven't heard much about artificial gravity from NASA. Larry Lemke, an engineer at Ames Research Center on assignment to study artificial gravity at the space agency's Washington headquarters, explains that zero-g is fine for short missions, the current staple of America's space program. In fact, learning how we adapt to microgravity and how to exploit it have been key research objectives.

"Zero-g is what you get if you go in orbit around the planet. And since people knew that, they made it an asset," Lemke says. "But if your goals are interplanetary travel, then you have to reassess."

Why, if zero-g works for short hops, couldn't we float around on long-duration flights, too? Mainly because the same physiological adaptations that allow us to overcome initial space sickness (yet another olde synonym for several days of lost lunch) and work comfortably in microgravity make the return to gravity rough. If we could stay in zero-g forever, no sweat. But what goes up must eventually come down, and it's got to be in good enough shape to do its work in the low Martian gravity or back on Earth's surface.

The most debilitating bodily changes caused by zero-g are deconditioning of the cardiovascular and skeletal muscle systems, and bone "demineralization." Calcium leaches from bones because they don't get the kind of impact exercise—running, walking—that stimulates marrow growth. A couple of things conspire to weaken the heart, including the shift of fluids toward the center of the body. "You're a water balloon," explains Paul DiZio, assistant director of the Graybiel Lab. "That's a simple model [of the human body]. If you had a water balloon in space, it would expand to fill the greatest possible volume and be perfectly round."

The same thing happens with the body in space. After the astronaut whizzes away a couple of now-superfluous pints of fluid, the rest pools around the chest. When blood no longer drops into the feet and legs, the heart doesn't have to struggle to pump it through the system. The lazy heart weakens. In fact, every muscle weakens, because the body simply doesn't get the workout it does in its customary tug-of-war with Earth's gravity.

"You don't realize how much force it takes just for you to sit in that chair. You call it resting, but if you were to totally relax, you would slump and fall in a heap on the ground. You'd look like a boxer that had just been knocked out," says DiZio, a psychologist with a gift for analogy.

Of course, that's what makes zero-g such a fun place to be, and coming home such a drag. Space travelers generally return to Earth with a condition called postflight orthostatic instability—Greekspeak for "our hero's back, but he can't stand up." Jerry Carr, veteran of the 1973 Skylab 3 flight that holds the U.S. space endurance record, says, "I didn't faint, but I felt pretty clumsy. My head felt like a big watermelon and I had to work hard to support it. I'd been a butterfly for 84 days and suddenly I weighed something again."

It's the slapstick but appalling prospect of a contingent of space butterflies taking one small flop for mankind on the Martian surface that has NASA minds engaged in finding antidotes to the effects of weightlessness. Even the shortest Mars journey would take 14 months round-trip; other scenarios last as long as three years, and experts anticipate the effects of readaptation will only worsen as missions get longer.

So how do we keep our astronauts from falling apart? Lemke notes that in this country we really haven't done the fundamental research that would give us a definitive answer. However, the Soviet space program has long been geared toward studying problems of prolonged piloted flight: They've developed a regimen that gets cosmonauts back on their feet—although not working at full Earthbound capacity—in as little as two days, after stays in orbit lasting up to a year.

In space, cosmonauts slog away on treadmills and bicycle ergometers for four hours, every day, six days a week. During waking hours they wear "penguin" suits, full-body get-ups with woven-in rubber bands that force automatic isometric exercise for the torso and legs. They take mineral supplements and electrolytes, hammer their fists against solid surfaces to stress arm bones, and chugalug mildly saline solutions prior to reentry to replace the fluids lost in the initial adjustment to weightlessness. For the last two weeks of flight, they slip into something a little less comfortable—the "Chirig" lower body negative-pressure device, which creates a vacuum around the legs to coerce blood downward again.

If all these pharmacological and mechanical gizmos make space travel sound like the health-spa-from-hell, they're nothing compared to the bizarre side effects of *artificial* gravity. The problem is that rotating a spacecraft creates not only centrifugal force—the useful stuff—but something called the "Coriolis effect," which wreaks havoc on the body's balance system.

Try picturing a huge clock with a sweep second hand in motion. Now imagine trying to walk a straight line along the hand toward the center of the clock; you can't, because the forward motion of the hand sweeps you off into, *whoops,* a slightly elliptical path instead. A more mundane example: because the Earth rotates, the Coriolis effect makes water *swirl* down the drain instead of dropping straight down the pipes.

When you consider that the semicircular canals of the inner ear—the things that (along with vision) control balance, orientation and whether you're going to toss your cookies—are basically no more than a set of tiny liquid-filled pipes, you can appreciate why NASA's interest in artificial gravity has led the agency to fund human response studies in the Graybiel Lab's rotating room.

And why I'm getting more anxious by the minute.

DiZio tries to calm me. "We have a pretty good idea when people are getting sick," he says less than reassuringly, enumerating ye olde clues: pallor, panting, perspiration, salivation. "If we see someone with a sweaty brow, we know they're feeling a little nauseous and we stop." And if they're drooling? His laugh holds a hint of Vincent Price. "Then it's probably too late."

The rotating room is actually a cylindrical chamber, 22 feet in diameter, turned by four banks of motors—the same kind that power the monorail at Disneyland. Built of submarine-gray aluminum sheeting over structural foam, the room is a decidedly grim-looking, totally enclosed, merry-go-round. There are no windows, no portholes. Once inside, with the door shut, you get absolutely no visual cues as to whether or not you're spinning in relation to the outside world.

To communicate with research associate Joel Ventura, DiZio wears a headset walkie-talkie with bobbing antenna that gives him a raffish John Belushi-the-killer-bee look. Ventura bolts the door from the outside, moves to the control room, scans the rotating room with a ceiling-mounted videocam to be sure he's got us in sight, and gives the okay for rotation over the speaker system.

Let the fun begin.

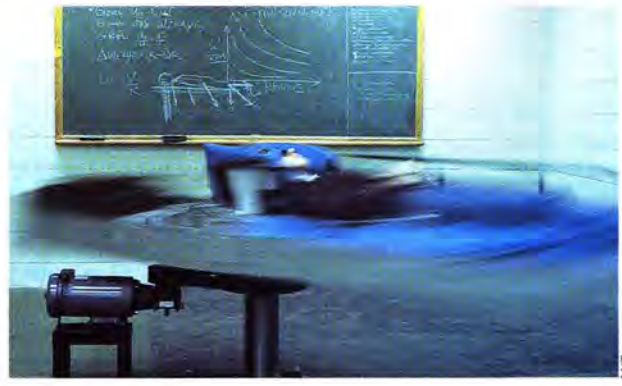
DiZio recommends I lean against the wall at first and keep my head still. We're going to take it up to 5 rpm and leave it there unless I beg for mercy—or for more. At that speed of rotation, at this radius, we'll get a combined force of about 1.45 g's. Although I know we're moving because the motors grind and then level off to a comforting starship-in-flight purr, I get no physical sensation of acceleration—perhaps because I'm pressed against the wall tighter than a dealer in a drug bust.

Piece of cake, I think. Then I turn my head to look at DiZio and all my semicircular canals scream, "Omigod, we're *spinnnnning.*" I swallow hard, will my stomach to stay in place, s-l-o-w-l-y move my head back to center, pretend I'm wearing a neck brace, and concentrate on keeping my eyes focused on a wall speaker directly opposite me. I'm so intensely involved with damping down my inner ear alarm system, I lose my grip on my pen. When it drops, it whips through the air in a bizarre Coriolis path and sort of zig-zags rather than rolls along the floor.

"Try to walk toward the center," DiZio says. He's gotta be joking. Game soul that I am, I look menacingly at the floor, unglue myself from the wall, and take what I think will be a normal step forward. Coriolis forces sideswipe me. I charge on with a drunk's locked knees and flat feet and find myself pushed farther and farther out of a straight line. DiZio notes that I'm leaning into the artificial gravity, toward the center, at about a 15 degree angle, but I'm starting to get pretty woozy and can't even respond, because all my attention is nailed to the elementary problem of locomotion.

When I stand still, look at the opposite wall, and move my head in an arc—left ear to left shoulder, then right ear to right—my field of vision pitches and yaws like a movie shot through a rocking camera. All this time, remember, the room is spinning around once every twelve seconds. Because I can't see the world zipping by outside, I don't perceive the rotation visually. All my information is coming from my inner ear, and it's telling me this is a crazy way to go to Mars.

DiZio, veteran of 200 parabolic zero-g jet flights and a guy with a self-proclaimed iron stomach, claims experiments suggest that volunteers can be gradually conditioned to ignore the horror show effects. But they have

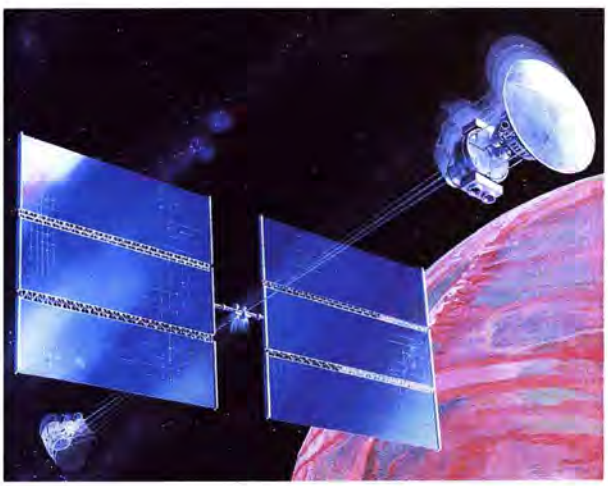


MIT

to then be *de-conditioned* to function in the real world again. Of course, DiZio himself copes at 5 rpm by moving his eyes eerily to look around—but never his head—and by taking small, shuffling baby steps that make him look like a comedian's parody of a geriatric case. On Joel Ventura's video monitor we must seem to be reliving an old episode of *I Love Lucy:* Ricky and Lucy stumble into a giant centrifuge. Is this any way to run a space mission?

Maybe not. Ten miles away in Cambridge, at MIT's Man-Vehicle Lab, Peter Diamandis, a 27-year-old hyperachiever with graduate degrees in aerospace engineering and an M.D. from Harvard, has a different idea for countering the effects of weightlessness—give astronauts a daily dose of artificial gravity while they're sleeping. With a grant from NASA, Diamandis has built an experimental Artificial Gravity Sleeper— a.k.a. "Robocot," or the rotating bed. Naturally, the concept spawns shtick about Hugh Hefner and mirrored ceilings, but the only slightly sexy features of the Sleeper are its hospital-issue water mattress and royal blue velour bedspread. The Sleeper is distinctly laboratorial: a sort of stainless steel examining table, cantilevered at the head from a cylindrical motorized base, housed in a bunker-like concrete room under a ceilingful of glaring fluorescent lights.

Diamandis mans a jerry-rigged control panel with more raw circuitry than the inside of a TV, and cranks the Sleeper up for a quick riderless demo spin. At 24 rpm—the speed required to create a 1-g force at the footplate—the bed swirls like a toppled windmill, kicking up a stiff little breeze in the lab. Diamandis puts on the brakes and turns to me. "Now, what I propose," he says, "is that you hop on board and I'll go at a much slower speed."



The "robocot" may provide an alternative to spinning spacecraft (below) as a means of creating artificial gravity in space.

Fine. I kick off my shoes and stretch out flat on my back, with the soles of my feet just grazing the footplate and my ears at the exact centerpoint of rotation—my head skewered, as it were, on the spindle of a record player. Diamandis buckles me down with a lapbelt, takes my glasses and gives me a borrowed-from-an-airline sleep-mask to darken any visual sensations of rotation. "Give me your hand, please," he says, placing my palm on a large red button at the edge of the bed. "This is the emergency stop." Emergency stop? Nervously, I crack bad ejection button jokes as Diamandis wrestles the windshield into place—a curved construction of clear Mylar over a paned metal frame. Feeling like a vegetable in a greenhouse, I put on the mask and brace myself for the ride.

Diamandis cautions me to keep my head still. The motor starts its electric shaver buzzing, and rotation begins and accelerates until it levels off at .5-g. I'm aware that the water mattress changes shape beneath my legs as the Sleeper speeds up and centrifugal force pulls water toward the outside of rotation—toward the foot of the bed. My feet, too, are now pressed into the footplate by an unaccustomed force that feels as I imagine attraction would feel to a magnet.

The ride is smooth, oddly soothing, and beneath the not-quite-opaque sleep mask, I can't tell whether I'm spinning clockwise or counter—or whether I'm spinning at all—except that Diamandis' voice dopplers in and out, and I get a slight sensation of light/dark/light/dark from a burned-out row of ceiling lights.

Diamandis cranks the Sleeper up to 24 rpm. The 1-g of artificial gravity pulls my feet so strongly I would swear the bed has tilted up at the head. When I raise my arms at my sides, my hands are pulled in parabolic motion by the Coriolis effect. I very cautiously turn my head from side to side. Because my eyes are shut, the effect isn't nauseating, but I get the same Coriolis-distorted sense of motion. It's weird, but not unpleasant. I am so relaxed, my impulse is to roll over on my side and settle in, but instinct tells me my semicircular canals would go wild.

As the bed slows to a stop, the pressure eases on my feet. My knees lower as the water in the mattress shifts back up under my backside. With eyes closed and the bed stopped, for the first time my head feels like it's spinning. After a few seconds, the sensation disappears. Diamandis removes the windshield, unbuckles the belt, and I sit up. I feel fine. I feel great. I'm a gyronaut, and I'd do it again in a heartbeat.

continued on page 61

INTERNATIONAL SPACE UNIVERSITY®
HEADING TOWARD ORBIT

The Birth of a 21st Century Institution

It is my pleasure to write a few words on behalf of an organisation I helped to start and which is close to my heart: the International Space University. ISU is an outstanding new institution dedicated to identifying, unifying and educating the world's best young professionals and outstanding graduate students involved in space-related studies from architecture and engineering to life sciences and business. Through its academic programmes, ISU is cultivating a new generation of leaders dedicated to the peaceful use of outer space.

After the phenomenal success of its inaugural summer session at MIT, ISU is setting its sights on the establishment of a permanent central campus during International Space Year (1992). In the next few years, ISU will expand to include multiple campuses at centres of excellence around the world—linked together via satellite, sharing an electronic library and data bases, offering live lecture transmissions and implementing modern technologies—to enhance cooperative research and development of space. One day soon, perhaps by 2001, ISU will have a campus where it is destined to be: *in orbit!*

ISU is doing more to promote and guarantee the peaceful and permanent development of space than any other institution I know. I have been a sponsor of ISU since its founding, and I hope that you will be able to join with me in supporting this unique educational endeavour.

Sincerely,

Arthur C Clarke

The International Space University (ISU) was founded in April 1987 at a conference held at the Massachusetts Institute of Technology (MIT). The ISU co-founders—Peter H. Diamandis, Todd B. Hawley and Robert D. Richards—forwarded a concept in space education which has captured the imagination and support of the world's space community. With the involvement of academia, governments and industry from numerous nations, ISU will expand into a full-year academic program and permanent campus locations following 1992, the International Space Year. "Clearly the ISU plans are quite ambitious, but the concept has won over many of its early doubters," notes Mr. Ian W. Pryke, head of the European Space Agency's Washington Office. "The momentum and success the ISU has built is why I am proud to serve as its Chairman of the Board."

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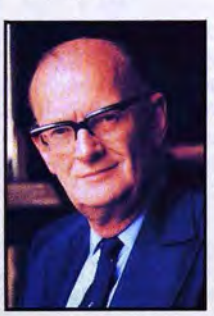


Arthur C. Clarke is the author of* 2001: A Space Odyssey. *He serves on the ISU Board of Advisors and is the Chancellor of the University of Moratuwa, Sri Lanka.

ISU Gains Momentum

continued from first page

The inaugural summer session of ISU was held at MIT in 1988, and brought together 104 graduate-level students and young professionals from 21 nations. ISU's first academic program provided an innovative package: a nine-week summer session involving a broad curriculum, state-of-the-art equipment and labs, design projects, and an international faculty and student body. During the program, all students participated in a total of 240 hours of lectures encompassing eight disciplines. The ISU academic program was led by a core faculty of 30, enhanced by more than 70 visiting lecturers representing today's leaders in the international space community.

ISU operates from its Executive Office in Boston, Massachusetts, USA, which is headed by Peter H. Diamandis and Todd B. Hawley

The 1989 summer session will take place at Université Louis Pasteur in Strasbourg, France from 30 June to 31 August. The structure of ISU'89 evolved from the ISU program offered at MIT in 1988: a nine-week session of interdisciplinary lectures and design project activities, and eight academic disciplines: Space Architecture, Space Business and Management, Space Engineering, Space Life Sciences, Space Policy and Law, Space Resources and Manufacturing, Satellite Applications, and Space Physical Sciences.

In conjunction with summer sessions, ISU is pursuing the goal of establishing a permanent campus during International Space Year (1992). Following the 1992 International Space Year, the ISU plan is to open first its Central Campus, later adding Satellite Campuses for advanced research and study in ISU disciplines in existing centers of excellence located around the world. At the permanent campus, worldwide satellite broadcasting of lectures will be routine; computer conferencing and networking, electronic library and database access will be used to link together the varied elements of ISU.

An ISU Founders Association has been launched to help establish ISU's permanent campus and to assure the continuation of this global experience for future generations. Founders Association members will help finance the planning, analyses, needs assessments, design and construction of permanent ISU facilities. Members of the Founders Association are determined to prepare a complete development plan for International Space University, and secure a sound financial base for its implementation.

The process by which humanity develops and explores space has changed in many critical ways over the last 30 years. Space is no longer the realm of the economic superpowers, nor is it a domain limited exclusively to scientists and engineers. Today space development takes place in an international, interdisciplinary arena. ISU seeks to provide a general understanding of technical and non-technical areas important to space development, and to gather together the leaders of tomorrow, allowing them to discuss common goals, motivations and ideas. The International Space University invites visionary men and women of all nations to join and support this critical mission.

ISU Captures the

The International Space University mission is to offer educational programs which are of relevance to today's space industry. From its inception in 1987, ISU has fostered increasing levels of support from a diverse international roster of corporations and agencies whose leaders recognize the value and impact of the programs offered at ISU.

"In this era of expanding civil space programs, there is an ever-growing interest and need in our industry to identify and train young people who can operate successfully in an international commercial environment," notes John McLucas, Chairman of QuesTech, Inc. "The ISU seeks to satisfy the emerging training needs of the aerospace industry."

ISU has pioneered a unique education niche which has proved as relevant to aerospace firms in North America, Japan

The Power of ISU

One hundred and four rare individuals now have friends and professional colleagues in 21 different countries of the world. These are the students of the first graduating class of International Space University. The ISU alumni form a cadre of dedicated space professionals who will provide the leadership to launch humankind into space.

To illustrate the effect the "ISU Experience" has already had, a sampling of alumni perspectives is presented here:

- "This has been the most important educational experience of my life," said Mark Matossian, the first alumnus to obtain graduate course credit for his work at ISU'88, and now a staff scientist at SAIC. "Never have I been asked to push myself as far and as fast as I did at ISU this summer."

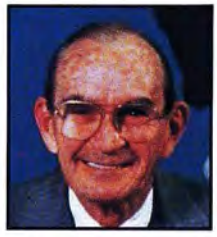
- "During ISU I made contact with individuals from many space-related corporations—many of them I have remained in frequent contact with, this will help to create new opportunities for all of us,"

Interest of Space Industry Leaders

Space industry leaders from over 20 nations have endorsed ISU.

Yasuhiro Kuroda
SHIMIZU

Claude Goumy
MATRA SPACE



Dean Burch
INTELSAT

and Europe as it has to telecommunications corporations in Africa and Australia. Proof of this relevance may be noted in Japan's increased participation in ISU in 1989, which will include at least 17 students—an increase from five participants in the 1988 program at MIT.

"We wish to promote the ISU program among Japanese corporations because we believe that space development will require professionals who have an international perspective and who will succeed in the increasingly cooperative world space industry," explains Dr. Yasuhiro Kuroda, Senior Advisor of Shimizu's Space Project Office, Japan's ISU Liaison since 1987.

"In Europe, the multi-national nature of many space activities makes the International Space University program particularly valuable," remarks Claude Goumy, General Manager of MATRA SPACE, which is sponsoring students and curriculum development for the ISU'89 program in Strasbourg, France. "I believe that the international educational experience of the ISU will have very great long-term benefits in our firm, our nation and the world."

At the INTELSAT Organization, 115 nations own and operate an expanding international satellite communications system which is often referred to as one of the best examples of successful multi-national space cooperation. "It has been our pleasure to support [the ISU] enterprise," notes Dean Burch, the INTELSAT Director General and a member of ISU's Board of Advisors. "It is extremely pleasing to see how successful the ISU program has become in such a short period of time."

Networking

says Akiyoshi Kabe of Mitsubishi Electric Corporation. "I know I am only a fax or a phone call away from hundreds of people—space experts, astronauts and CEOs—who are not only my colleagues but also my friends."

- ISU Alumna Marina Aguiar of Brazil adds: "ISU gave me an excellent understanding of how my work in materials science can be used in the development of space, and the multicultural environment helped to broaden my view of the world."

- Vadim Vlasov, a Soviet alumnus very active in US-USSR relations, noted: "I was impressed with the expertise, diversity and enthusiasm of the ISU faculty. It was extremely interesting for me to hear the perspectives of faculty from 14 nations."

- "Immediately following ISU, I was offered a job by the Canadian Astronaut Program. As one of my first assignments I was sent to the Soviet Union to discuss experimental procedures and logistics for two Canadian experiments to fly on Biocosmos 1989," says Canadian Alumna Kristiina Valter. "My friendship and experience with my 12 Soviet ISU colleagues was invaluable in this trip to the USSR."

ISU'88 graduates Mark Matossian (USA), Akiyoshi Kabe (Japan) and Kristiina Valter (Canada)

The shaded regions on this world map represent those nations which sent their top students to ISU'88

- Russel Hannigan is the youngest member of the British Aerospace Hotol research and development group. He notes, "My experience at ISU and the design project activities allowed me to work with a culturally diverse group of people, and also gave me the opportunity to gain knowledge which is valuable to my work at British Aerospace."

- "When I returned from ISU I received a very important job proposal from Aeritalía, and now I am in Torino (Italy) working on the Human Factors Aspects of the Columbus Space Station," says alumnus Francesco Brunelli. "I really do have to express my warmest gratitude to ISU. I owe it all to ISU."

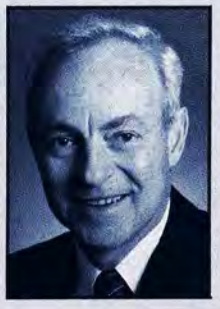
Between 20 June and 20 August 1988 a group of outstanding students and young professionals came together as strangers and left as friends and colleagues. Coming from 21 different nations, but sharing a common dream and the qualities of perseverance, leadership and brilliance—these students have set out to change the world...together.

Investors in Space Leadership

The 104-member ISU Class of 1988 at MIT

Over 70 corporations and government agencies in more than 20 nations joined to support the ISU program when it began in the summer of 1988. Over US$1 million was raised to finance ISU Executive operations and the innovative ISU'88 program held at the Massachusetts Institute of Technology. In 1989 and beyond, ISU seeks to expand its network of supporters to include individuals and institutions to provide scholarships, curriculum and permanent campus development. Space Biospheres Ventures has already commited a five year scholarship and Life Sciences curriculum support to ISU. "We are delighted with the ISU program, level of excellence and international scope, and are proud to be sponsoring ISU's first textbook this year in the field of Space Life Sciences," says Margret Augustine, CEO and Project Director, Space Biospheres Ventures.

European Space Agency Director General Reimar Lüst has noted that, "[ESA] supports not only the 'principle' of the ISU, but also its day to day activities. To date this has included free advertising in Agency publications, ISU brochure sponsorships and, in conjunction with the 1988 summer session, ESA sponsored scholarships and ESA staff as visiting lecturers." Lockheed Corporation has contributed a senior executive to serve full-time on the ISU summer session faculty for two months each in 1988 and 1989. "ISU is an important force for international space education and awareness. Few programs offer a more inventive and forward thinking approach to this vital frontier," says Lockheed Chairman and CEO Daniel Tellep. "We applaud ISU's efforts and are proud of our company's role in its continuing success."



ISU supporters, Margret Augustine of Space Biospheres Ventures, Reimar Lüst of the European Space Agency and Daniel Tellep of Lockheed Corporation.

ANNOUNCEMENT

An ISU Founders Association has been established to provide a vehicle for visionary men and women to become involved with and to support ISU's transition to a permanent campus in 1992. For more information on the Founders Association, contact:

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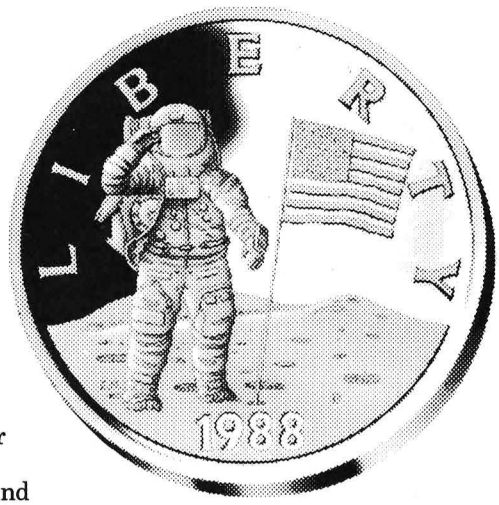

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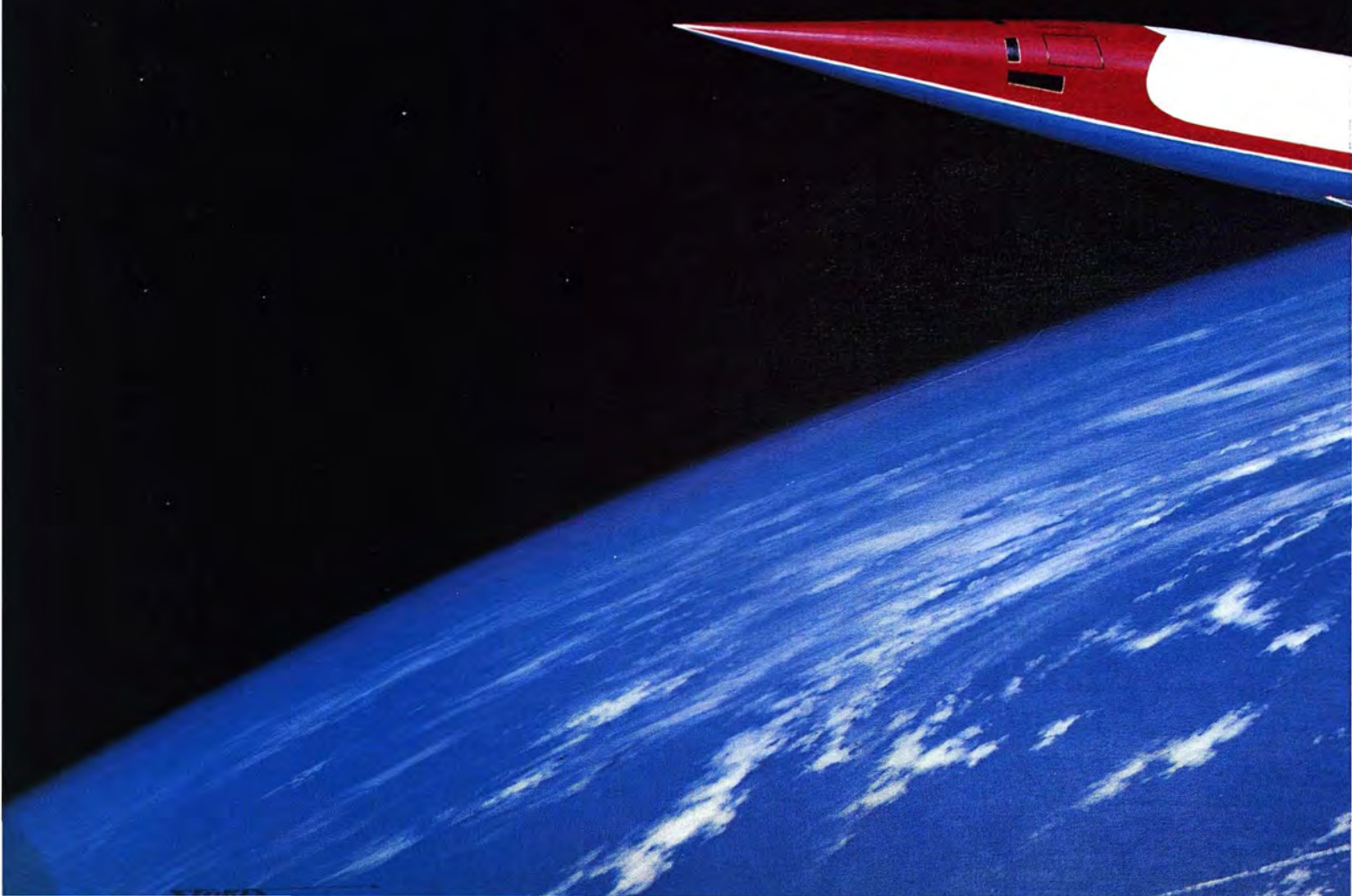
2015: THE AGE OF SPACEPLANES

Flying the friendly skies of the future—at Mach 25.

By T.A. Heppenheimer



One by one, the four long, sharp-nosed craft emerge from their Cape Canaveral fueling facilities, towed by a boxy white vehicle hitched to the nose landing gear. Each in turn taxies into position at the end of the runway. A great roar booms across the flat Florida grassland, as a nearly transparent hydrogen flame fills the cavernous exhaust area on each craft's underside and blasts to the rear. Ponderously at first, then with increasing speed, each spaceplane gathers headway, finally zooming from the runway in a swift climb steeper than that of any airliner. Fifteen minutes later the last one is gone, leaving behind only the fading echoes of skyborne thunder.

Although winged spacecraft have been carrying astronauts to orbit since 1981, never before have two vehicles been in flight at the same time. But on this Fourth of July in 2015, a squadron of *four* American spaceplanes will fly to orbit, virtually in formation. They'll be joined by two European spaceplanes and two from Japan in a dramatic meeting at the International Space Station.

These aren't rocket-powered craft, but true airplanes—able to fly in the atmosphere, reach orbital altitudes above 100 miles and return to Earth at the end of their missions. Both NASA and the Air Force, as well as foreign governments, own and operate these "ultimate aircraft."

The Air Force particularly appreciates the ability to scramble into orbit on as little as an hour's notice. During a military exercise in November 2013, pilots flying F-23 interceptors launched anti-satellite missiles to destroy an obsolete spy satellite in orbit. By the end of the day an Air Force spaceplane had lofted a replacement.

Other spaceplanes fly reconnaissance missions, having replaced the old, slow SR-71 Blackbirds of prior decades. Military planners laud the spaceplane's ability to follow unpredictable paths, unlike the spy satellites whose orbits can be predicted weeks in advance. Reconnaissance spaceplanes can even choose their speed and altitude, descending into the atmosphere to evade killer laser beams or take particularly sharp photos.

NASA, the Europeans and the Japanese sometimes use spaceplanes to launch satellites, but their prime task is to ferry astronauts to and from orbiting space stations. Back in the days of the U.S. and Soviet space shuttles (and of Europe's smaller Hermes), critics often noted that the work done by astronauts was all very interesting, but that each flight cost up to several hundred million dollars. The advent of spaceplanes early in this century cut the price tag by 90 percent, while reducing the time required to plan a mission from years to weeks.

As a result, the flight of astronauts has become practical and routine. Orbital science has moved beyond the old-time hype about "revolutions" that would spring from work conducted on space stations. The space bases of 2015 are valued for their true worth, as international research centers on a par with the best labs on Earth.

Although they use different techniques to get to orbit, all three spaceplane fleets—European, Japanese and

McDONNELL DOUGLAS CORPORATION

American—are operated like airlines, with small ground crews to prepare the vehicles quickly for flight. This is a marked improvement over earlier space shuttles, which demanded several thousand people working for months before each launch.

Of all the spaceplanes, Europe's Saenger is the least straightforward in its journey to orbit. It features a small winged orbiter, rocket-powered, that rides piggyback atop a hypersonic airplane. Following takeoff from Toulouse in the south of France, the booster airplane cruises at an altitude of 80,000 feet. It heads southwest, around the western bulge of Africa, until it reaches the desired latitude—in this case 28.5 degrees north for a rendezvous with the space station. A satellite launch mission would take it on an equatorial course above the Gulf of Guinea.

In a gradual turn, Saenger heads due east and rises to 100,000 feet. As it flashes across the empty wastes of the Sahara Desert at Mach 6.8, it lays down a heavy sonic boom. The winged mini-shuttle separates and flies to orbit using its own fuel. Meanwhile, the booster airplane turns again and retraces its course back to Toulouse.

Similarly, the winged second stage reenters the atmosphere and glides from its orbit to the higher latitude of Toulouse. After an unpowered landing, it is serviced and reunited with its booster.

U. S. Companies are now competing to design the National Aerospace Plane, shown here in three different artists' concepts. The German Saenger (below) will have a passenger shuttle mounted on a hypersonic first-stage vehicle.

By contrast, the Japanese spaceplane packs everything in one single-stage vehicle. Its modified rocket engine "breathes" oxygen from the atmosphere, rather than carrying it in liquid form as an oxidizer to burn hydrogen fuel. This greatly improves the spaceplane's performance, since tanked oxygen is very heavy. (20th century engineers used to quip that carrying liquid oxygen during a rocket's ascent through the atmosphere was like a fish carrying water in a canteen!)

It wasn't easy designing the technology to feed air into the engine, however. Rockets characteristically work at high pressure, and the outside air must be pumped to an even higher pressure to enter the engine. The Japanese design is called "LACE," for Liquid Air Cycle Engine. It relies on supercold hydrogen to chill and liquefy the incoming air. Once in a liquid state, it's easy to pump this air to very high pressures.

Japan's spaceplanes use LACE engines during takeoff and acceleration to Mach 5. By then the craft is at 85,000 feet, where the air becomes too thin to be useful. Only then does the plane switch over to tanked oxygen, proceeding the rest of the way to orbit as a hydrogen-burning rocket.

America's spaceplanes are equally innovative, operating with another new engine called the "ejector scramjet." When the craft flies at high speed, air rushes through carefully-shaped ducts mounted on the underbelly. Fuel injectors then spray hydrogen into this airflow, heating and blasting it out the back to create thrust. But this arrangement needs something extra at both ends of the flight. At low speeds—below Mach 3, for instance—the airflow is too slow for the scramjets to work properly. Above Mach 20, as the craft approaches orbit, the air is too thin.

Small rockets called ejectors solve both problems. During the early stages of flight, the ejector's exhaust plume sucks in a flow of outside air. Hydrogen burned in this airflow adds to the thrust of the ejector, allowing the spaceplane to take off and gain speed. Above Mach 20, this same ejector functions as a rocket in its own right, giving the extra thrust needed to reach orbit.

None of these spaceplanes was created overnight; all trace their origins back to the late 1980s. In Japan, a blue-ribbon space policy committee laid out

continued on page 60

MBB/ERNO

GENERAL DYNAMICS

ROCKWELL INTERNATIONAL

The Magellan spacecraft, built from leftover parts, is about to head off for one Hell of a planet.

UNVEILING VENUS

IF it's extraterrestrial life you're looking for, or likely spots for off-Earth industrial development, Venus is probably not the place for you.

Rocks on the planet's surface glow faintly at temperatures of 900 degrees Fahrenheit, or half a turn past the hottest "broil" setting on your oven dial. The Venusian air is 90 times as dense as sea level air on Earth, and is almost entirely carbon dioxide. The clouds are laced with sulfuric acid. If you survived the descent through them to step outside, you'd be simultaneously crushed and fried. Venus is one of those places in the Solar System (Jupiter's interior is another) that makes hell look like Club Med.

So why send a space probe there?

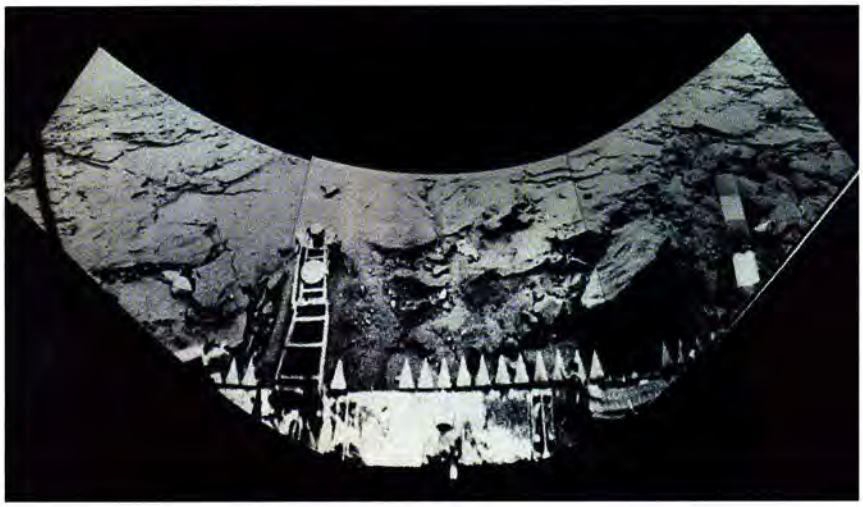
"I'm quite comfortable saying that science is the only justification for it," says James Head, a planetary geologist at Brown University and a member of the science team for the upcoming Magellan mission to Venus.

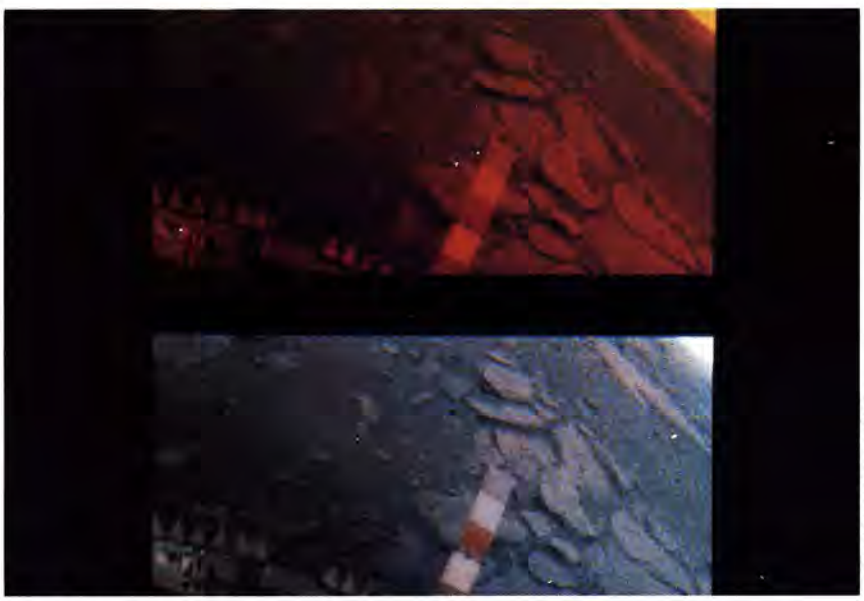
"I'm not talking about anything like those first Voyager close-ups of Jupiter's Europa or Saturn's rings. That's exploration and fascination. I'm talking about science. I'm talking about peering down from orbit through the Venusian smog and obtaining results that tell you something fundamental about the way planets work."

Equipped with radar for mapping the surface of Venus in unprecedented detail, the Magellan probe is about to be launched toward its destination from the space shuttle this spring. The launch "window" lasts from April 28 to May 24. If that opportunity is missed, it will be another two years before the planets are again properly aligned.

Magellan's send-off will be an historic first in its own right. No planetary mission has ever used the shuttle as a booster; in fact, no new planetary mission has been launched by this country since 1978, when a Pioneer orbiter was sent toward Venus. The shuttle era has

By Charles R. Pellegrino





U.S.S.R. ACADEMY OF SCIENCES

Soviet Venera orbiters used radar to map part of Venus' northern hemisphere in 1983 (top), including the region around Maxwell Montes, a large, possibly active volcano. Soviet landers have also returned photos from the rocky surface; the bottom image is shown both in "natural" and white light.

been a time of severe drought for U.S. Solar System exploration, full of delays and dashed hopes. Magellan itself has had three different names since the project was first proposed, and at least as many launch dates.

But planetary scientists are hoping that this mission will mark an end to the bad times. Testing of the spacecraft was successfully completed last summer, while scientists practiced taking radar images of Venus-like landforms in the Mojave Desert. Magellan was shipped to Kennedy Space Center in Florida last September, a month ahead of schedule, and now awaits its launch from Atlantis on April 28.

That same day, after climbing to an orbit 160 miles above Earth, the shuttle's astronaut crew will open the vehicle's doors to allow Magellan to spring out of the cargo bay. The probe will then fly off on its own trajectory using an attached upper stage rocket. Fifteen months (and one and a half revolutions around the Sun) later, it will arrive in a nearly polar orbit around Venus. There, after a brief checkout period, the probe's radar instrument will begin the laborious task of mapping the planet's cloud-hidden surface, one narrow strip at a time.

In terms of bulk composition and size, Venus and Earth are virtual twins: A person standing on Venus would weigh almost as much as on Earth. But one difference between the "twins"—perhaps *the* difference—is that Venus has always been closer to the Sun.

Four and a half billion years ago, after the Sun's initial fires had dimmed to a warm glow, Venus, Earth and Mars lay as dry and dead as old bones, stripped entirely of whatever ice and vapor had once covered their surfaces. All three worlds were airless and Moon-like, but they also were volcanically active. Water and other volatile elements percolating up from within could now remain bound gravitationally instead of blowing away on the solar wind.

In those formative years, when the Sun was cooler than it is today, water might have rained down upon the Venusian surface. But any shallow seas would have been obliterated early in the planet's history. What would ordinarily have swelled over time to form actual oceans (had Venus orbited farther from the Sun) instead evaporated to form dense clouds of water vapor.

The vapor acted as a heat trap for the Sun's infrared radiation, which in turn prevented the recondensation of lakes and seas. High in the atmosphere, sunlight split the water molecules into hydrogen and oxygen. The lighter

Magellan's radar will map a narrow strip of the Venusian surface on each orbit, then relay the data back to Earth.

hydrogen floated up to the edge of space and, at Venus' distance from the Sun, began blowing away on the solar wind. The heavier oxygen, meanwhile, fell toward the surface and combined with carbon to form carbon dioxide, the ultimate "greenhouse gas." Two billion years from now, when the Sun is expected to burn brighter— perhaps sooner if we aren't more careful—Earth will suffer the same fate. By exploring Venus, we may be glimpsing our own future.

The planet for which Magellan is headed is quite different from its terrestrial "twin." It has no moons and no magnetic field, and it rotates east to west, in a direction opposite from Earth. Venus also spins very slowly—243 days for a single turn on its axis, making the Venusian day three weeks longer than its year.

Magellan will be moving north to south during the closest part of each orbit, when it will map a narrow strip of the surface. Then the spacecraft will loop out and away from the planet as it transmits the data back to Earth. Over the course of eight months, nearly every point on Venus will pass at least once beneath Magellan's gaze—an operation something like eating corn on the cob while slowly turning the cob. The final map will be made of successive, overlapping strips, with only the south pole left unexplored.

Magellan carries no cameras, at least not in the conventional sense. Because Venus is shrouded completely in clouds, with never a break showing through to the surface, a spacecraft can't look down and photograph mountains, valleys and crater fields as we were able to do at Mars. Instead, Magellan uses a device called Synthetic Aperture Radar, which has been used to build detailed images of the Earth and its oceans.

Radar pulses from Magellan will pass with impunity through the Venusian cloud cover, bouncing off the planet's rocky surface and returning to the spacecraft's radar receiver. Individual features on Venus will be "imaged" based on the time it takes for the signal to return and how it is distorted by Doppler shift. At the same time, an altimeter will be able to resolve height variations in the Venusian mountains and valleys as small as 100 feet.

More than a decade ago, NASA sent the Pioneer Orbiter to Venus equipped with a more primitive radar system than the one Magellan carries. It mapped 92 percent of the Venusian surface, but unless a boulder happened to be seventy miles wide, it would have been too small to show up in the pictures.

Still, Pioneer was able to reveal major landforms on Venus, including the "continents" of Aphrodite and Ishtar, the rugged highland regions and the vast lowland plains. While these crude maps hint at such things as an asteroid crater almost as large as Australia, the individual hills, valleys, fault lines and lava flows from volcanoes (if these

exist) have never been seen.

In 1983, the Soviet Union placed two radar-equipped Venera spacecraft into Venusian orbit. But the state of the art at that time permitted the resolution of peaks and troughs no smaller than two miles across, and due to their cigar-shaped orbits, the probes were able to provide close-up coverage of only 30 percent of Venus near the North Pole. Ground-based observations using the giant radio telescope in Arecibo, Puerto Rico can match Venera's resolution, but are also limited in coverage.

With the Magellan probe, scientists will be able to distinguish features on the Venusian surface as small as 250 to 300 meters across. That's like being able to look down from space and distinguish the contours and city blocks of Manhattan, when the only things you could have seen on previous radar images were large mountain chains.

There was a time in the history of American planetary exploration when every spacecraft had at least one backup ready to complete a mission if the first probe failed, or to be sent to a second location if it proved successful.

But there is no spare probe to fling toward Venus. Magellan is one of a kind, scavenged together from leftover Voyager, Galileo and even Mariner hardware, and equipped with only one new science instrument: the radar mapper.

Still, James Head is delighted. "The key thing about Venus is that it is the last stage in the exploration of the inner Solar System," he says. "It is the missing link in terms of our understanding of the terrestrial planets."

Indeed, we know very little about our Earth-like neighbor. A handful of Soviet landers have dropped down to the surface and photographed the cracked volcanic rocks. The French and the Soviets have sent instruments drifting through the atmosphere on balloons. But we've seen almost nothing of the topography of Venus.

Aside from giving us more information for drawing conclusions about the evolution of planets, says Head, Magellan will allow us to "take a look at the surface of Venus and ask, 'If it's like the Earth, *how* is it like the Earth? And if it's not like the Earth, *why* is it different?'"

Head points out that most geologists are caught up in examining the fossil-bearing geologic strata on Earth, which reveal only the last few hundred million years of the historical record. We rarely think seriously about the first half of Earth history—the more than two billion years when our planet was

MAGELLAN

Purpose
To map up to 90 percent of the surface of Venus in unprecedented detail, using cloud-penetrating radar.

Launch: April 28, 1989 (Launch "window" lasts until May 24)

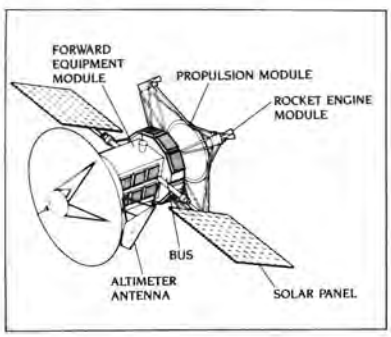
Arrival in Venus orbit: August 10, 1990

Mapping mission begins: August 28, 1990

End of main mission: April 28, 1991

Highest point of spacecraft orbit around Venus: 4,978 miles

Lowest point: 155 miles



■ Magellan and its attached Inertial Upper Stage booster will be released from Atlantis during the shuttle's fifth orbit. The booster will then be fired to send the probe on its way to Venus.

■ The spacecraft will orbit the Sun one and a half times before arriving at Venus. Onboard rockets will then fire to place it in orbit around the planet for a 243-day mission.

■ Magellan will take three hours, nine minutes to complete each orbit. For 37 minutes (when the spacecraft is closest to the planet) the radar instrument will map the surface. The rest of the egg-shaped orbit is taken up with calibrations and relaying data to Earth.

■ The radar instrument will reveal surface features as small as 250 to 300 meters (about three football fields) across, and will detect height variations with a resolution of 30 meters.

Magellan's electrical power is supplied by solar panels. Its 12-foot dish antenna (used for the radar experiment) and spacecraft "bus" are hand-me-downs from the Voyager program.

Venus Vital Statistics

Radius: .95 (Earth = 1)

Mass: .82

Distance from Sun: .72

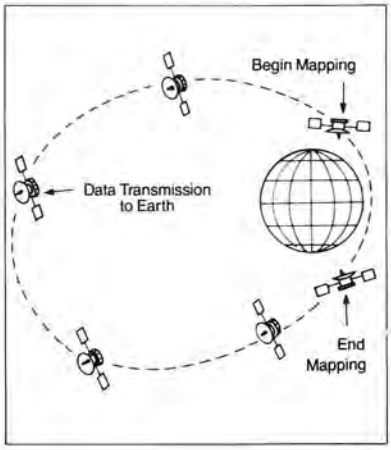
Length of day: 243 Earth days

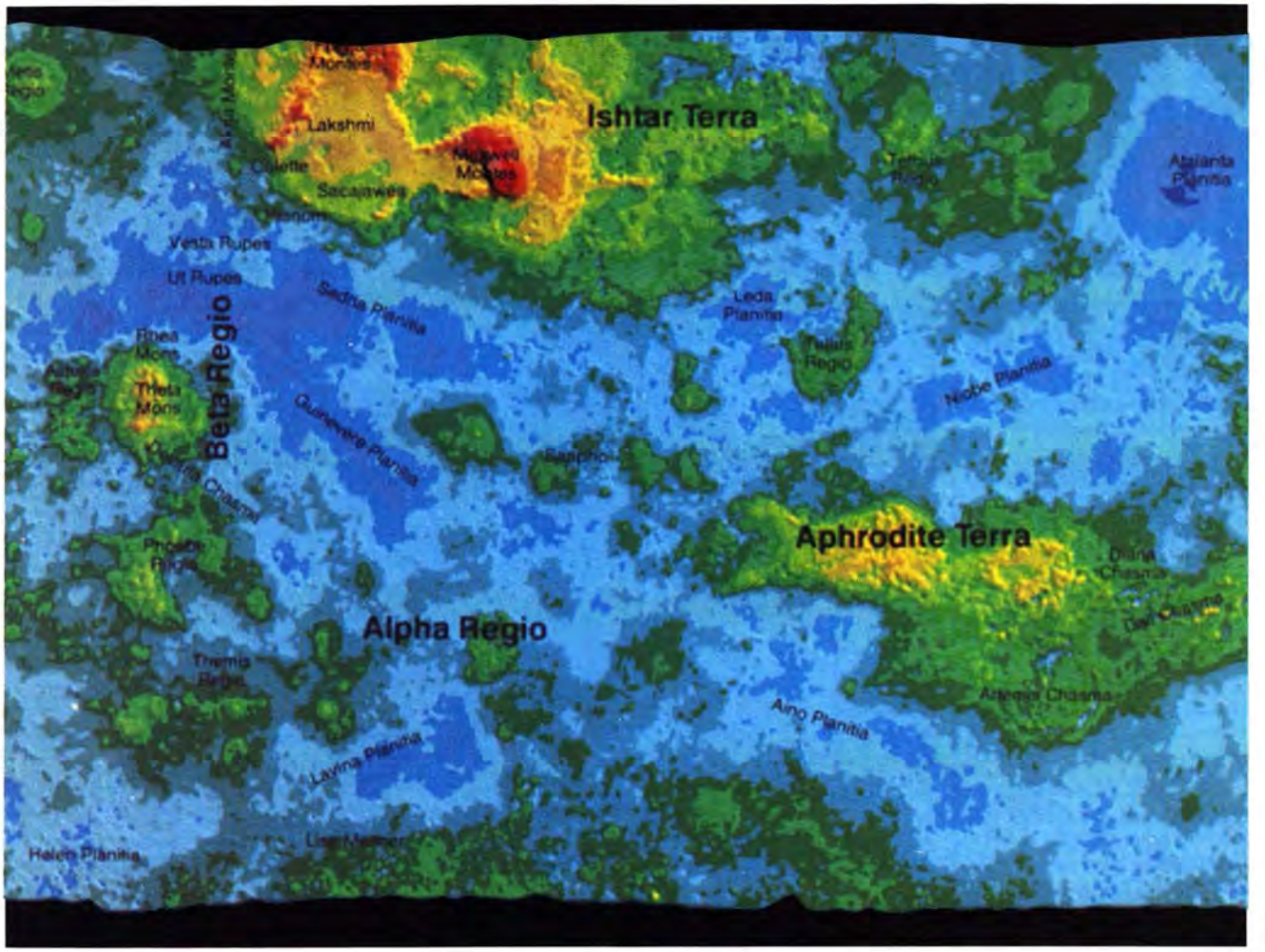
Length of year: 225 Earth days

Surface temperature: 900° F

Atmosphere: Carbon dioxide (96%), nitrogen and trace elements

Moons: None





Pioneer Venus radar data showed the planet's major geographic features, with highlands appearing green and yellow, and low areas blue. Magellan (opposite) will produce a much more detailed map.

being shaped. We don't have a very good idea of what was happening then, because the Earth is a commotion of winds and tides, and most of the evidence has been erased.

Says Head: "Venus, if it is different from Earth, could tell us what Earth was like when its surface was warmer, say, about four billion years ago. So there's a big link with Earth. The mapping mission is going to tell us one hell of a lot about the nature and history of the Earth."

We know already that there are Venusian plateaus as large as Australia, and something that *looks* like a land-locked version of the mid-Atlantic ridge that is now, even as you read, pushing Europe and North America apart at about the same rate as human fingernails grow.

"Yes, but is it really a divergent plate boundary?" wonders Head, referring to the huge crustal plates that ride on convection currents in the Earth's interior, causing continental drift. These shifting plates have carried bits of China across thousands of miles of ocean floor as though they were parcels on a conveyor belt, and plastered them against California. Plates have crashed India into China and pushed up the Himalayas between them. The same process is presently prying Egypt and Israel apart to create a new ocean—the Red Sea truly is parting, on a time scale unimaginable to Moses.

"We like to think we are seeing continental plate boundaries—things comparable to the Red Sea and the Himalayas on Venus," says Head. "But to move in and look at it in detail is what we really want to do, to see whether [the boundaries] exist or not."

Detail is what Magellan's map will provide. If there were oceans on Venus in some primitive past, the map may even show ancient shorelines. After the spacecraft's main mission ends in April 1991, exactly two years to the day after launch, scientists hope to use the orbiter to map the southern regions it will have missed, and to conduct studies of the planet's gravity field.

As we send our electronic sensory organs forth into the frontiers of the night, radar and cameras at the ready, a new field of comparative planetology is emerging, and we are beginning to understand our place in the Solar System. "What good is that?" scientists like James Head are often asked. "What's it going to do except make a few scientists happy?"

The answer is that you never know. We acquire new knowledge and develop new technologies, and we never can tell what they may one day be used for. Eighty-eight years ago, President William McKinley was shot while touring a science exhibit. The new x-ray machine only a few steps away might have saved him—no one thought to use it for locating and removing a bullet. The Chinese say they have found the skeleton of a Stone Age man who froze to death only two meters from an outcrop of coal.

You never know. □

Charles Pellegrino is a scientist and the author of several books on science and exploration, including Chariots for Apollo: The Untold Story Behind the Race to the Moon.

MISSION FILE

STS-29

LAUNCH:
9:57 A.M. EST, March 13, 1989, Pad 39B, Kennedy Space Center, Florida
LANDING:
6:36 A.M. PST, March 18, 1989, Edwards Air Force Base, California
ORBITER:
Discovery
ALTITUDE:
160-177 nautical miles
CREW:
Michael L. Coats, Commander
John E. Blaha, Pilot
James F. Buchli, Robert C. Springer, James P. Bagian, Mission Specialists
PRIMARY PAYLOAD:
NASA's fourth Tracking and Data Relay Satellite (TDRS-4)
OTHER PAYLOADS:
SHARE
CHROMEX
Protein Crystal Growth
IMAX camera
Chicken Embryo Development
Effects of Weightlessness on Healing Bone

For the second time in six months, Discovery and a five-astronaut crew were assigned to carry a NASA Tracking and Data Relay Satellite into orbit. Unlike the first post-Challenger mission last September, however, this time there was a full slate of science and technology experiments on tap as well.

DAY 1

After a hold of nearly two hours for ground fog and high-altitude winds, Discovery made a picture-perfect ascent into orbit. On the way up, the astronauts looked for and photographed debris from the shuttle's huge external tank. Shuttle managers suspected bits of the tank's insulation had damaged Atlantis' thermal tiles on Mission 27.

Six hours into the mission, Discovery's crew prepared to release their primary cargo, the Tracking and Data Relay Satellite (TDRS). There was a flurry of anxiety just nine minutes before deployment of the satellite and its attached Inertial Upper Stage (IUS) booster, when onboard instrument readings falsely indicated failure of two IUS computers. Mission controllers quickly resolved the problem, and the TDRS/IUS combination gently sailed out of Discovery's cargo bay. Seven hours and two successful rocket burns later, TDRS-4 was on its way to its test and checkout location at 150° W. Longitude.

A fully operational TDRS system will allow NASA to close or transfer almost all of its expensive ground tracking stations, ultimately saving $27 million annually.

DAY 2

Discovery's crew activated experiments and tested the orbiter's Text and Graphics (TAGS) system, a super-fax machine that receives photo-quality images.

The Space Station Heat Pipe Advanced Radiator Element (SHARE), an experiment to test liquid ammonia convection cooling for space station Freedom, shut down automatically after only ten minutes when heat built up too quickly for the ammonia to transport it down the pipe's 51-foot length to a space radiator. The astronauts later re-activated SHARE but shut it down after only two hours, again because of overheating. CHROMEX, an investigation of plant root growth in zero-g, also experienced electrical problems, forcing the astronauts periodically to take manual temperature readings.

The astronauts reported good Earth photography runs using the large-format IMAX camera; the film obtained during the mission will be made into a new IMAX movie to replace *The Dream is Alive*. They also obtained samples from the Protein Crystal Growth (PCG) experiment that investigators hope may lead to new pharmaceutical drugs for use on Earth.

There was a drop in pressure in one of the hydrogen tanks feeding the orbiter's fuel cells that provide electricity. As a precaution, Mission Control told the crew to turn down the cabin lights and shut off unnecessary electrical equipment.

DAY 3

Early morning TV images sent down by Discovery's astronauts showed the orbiter traveling tail-first into a magnificent sunrise. It was the first of several telecasts that day intended to give Earthbound watchers a feel for what it's like to fly, live and work in space.

In the afternoon, astronaut-

physician Jim Bagian and Discovery's commander Mike Coats demonstrated an ultrasonic medical experiment designed to measure blood flow in weightlessness ("I can actually confirm that there *is* blood flow in Mike's brain," quipped Bagian). Later, pilot John Blaha gave viewers a tour of the orbiter's mid-deck area. There were light moments as the camera picked up the signs and stickers mounted by the astronauts to give their spaceliner a homey touch. Most eye-catching was a tribute to the Shuttle Mission Evaluation Team that processes requests for action called "chits": A large emblem emblazoned with a Texas-sized cowboy boot honored the team's prowess as—what else?—"Chit Kickers."

SHARE again was deactivated after only 28 minutes. Engineers on the ground theorized that bubbles were forming in the liquid

NASA's fourth Tracking and Data Relay Satellite (opposite), was launched just six hours into the flight. The crew took this unique photograph of the jettisoned external fuel tank (top), and later filmed the Earth's surface with a variety of cameras.

ammonia during the device's re-heating cycle. More successful were the "AMOS" tests, as sensors at the Air Force Maui Optical Site got two good data takes when Discovery passed over the Hawaiian Islands. The cooperative project between NASA and the Air Force allows precise calibration of the electro-optical instruments on Maui.

The astronauts received a "GO" to power up all of the spacecraft's lights and systems after the recalcitrant hydrogen tank began to work at the proper pressure and temperature.

DAY 4

Discovery's crew put in their own "wake-up" call to Mission Control with a recorded message from actor William Shatner as his *Star Trek* alter ego Admiral Kirk. Also on the astronauts' agenda was a phone and video linkup with President Bush. The President praised the mission's success and vowed "to go forward with a strong, active space program."

Mission specialist James Bagian sorts through audio cassette tapes (used for recording biomedical data) in the shuttle's mid-deck.

Student researcher John Vellinger watched as the crew performed maintenance on his chicken embryo experiment. The goal of the experiment was to determine if chicken embryos can develop normally when exposed to zero-g, which may have implications for humans' ability to live and procreate in space.

The astronauts made yet another attempt at running the balky SHARE. Jim Buchli tried a labor-intensive technique of turning the heaters on and off manually, which initially produced good results. When SHARE was allowed to run automatically, however, some segments dried out.

DAY 5

Before Discovery's astronauts stowed their gear and deactivated experiments for the return trip home, there were a handful of mission objectives to meet. One involved navigational sightings on the Sun to determine if the orbiter's Inertial Measurement Units could be aligned in an emergency.

The crew wrapped up the experiment on bone healing

in weightlessness, in which four rats had tiny holes drilled in non-weight bearing bones. Student investigator Andrew Fras hoped to determine if bone calcium loss during spaceflight impeded the body's ability to heal fractures. And mission specialists Bob Springer and Jim Bagian reported on the success of the crystal growth experiment, noting that it had produced "some of the finest crystals we've gotten samples of so far."

DAY 6

As a record crowd of 450,000 people gathered in the Mojave Desert to watch Discovery land, the astronauts were notified of a minor change in the flight plan: The mission would end on the concrete runway at Edwards rather than on the dry lakebed.

NASA had hoped to find out how well the shuttle flies like an airplane by landing in a crosswind. When winds across the dry lake died out, the backup plan to perform tests of the spaceplane's revamped brakes was substituted.

"Now the fun begins." Blaha, Bagian, Coats, Buchli and Springer (left to right) pose with their spaceliner on the landing strip at Edwards.

The astronauts fired Discovery's maneuvering engines to come home as they swept over Madagascar. During the fiery reentry there was no loss of telemetry and only a brief dropout of voice signals. The ability to transmit through the TDRS-3 satellite launched last September, coupled with the 28.4 degree orbital inclination of Mission 29, eliminated the usual communications blackout.

Long-range cameras at Vandenberg Air Force Base picked up amazingly clear pictures of Discovery as it zoomed over the California coast at 150,000 feet. Just minutes later, Mike Coats and John Blaha brought the orbiter in over the Mojave Desert to execute another flawless shuttle landing.

NASA officials were exuberant. Already they were looking forward to the Magellan and Galileo planetary missions, and the launch of the Hubble Space Telescope in December. Dick Truly, the agency's associate administrator for space flight, neatly summed up NASA's attitude in four words:

"Now the *fun* begins." □

BACKYARD UNIVERSE

The Happy Looker

Sometimes amateur stargazers can help out the pros

▼ ▼ ▼

By Blaine P. Friedlander

Terry Meyers volunteered his six-year-old son, Nicholas, for patriotic duty. The father and son trained at their Racine, Wisconsin, home at night, under cover of darkness, to strengthen their ocular muscles. They risked blind spots, lunar luminous hypnosis and—most dreaded of all—missing Cosby.

Meyers and more than 1,500 volunteers nationwide were participating in a simple yet valuable mission: To watch for the Moon. This massive observational experiment, dubbed "Moonwatch 1988," was directed by the U.S. Naval Observatory in Washington, D.C. and NASA's Goddard Space Flight Center in Greenbelt, Maryland. The results showed precisely where U.S. observers could catch the first visible sliver of a New Moon.

For an hour and a half on the night of the experiment, Terry and Nicholas Meyers searched for the New Moon. They didn't see it, but that didn't extinguish a budding amateur's enthusiasm. "We camp a few times a year up in northern Wisconsin," Meyers says. "From there we can pick up the cloud of the Milky Way. It's a very dark location."

Data gathered by the volunteers—among them kids, retirees, housewives and corporate executives—proved to the professional astronomers that western locations can see a New Moon better than their eastern partners.

Amateurs with backyard telescopes rarely come up with the kinds of stellar discoveries that make headlines, but their observations can be valuable to the community of professional astronomers, nonetheless. One organization looking for a few good amateurs is the American Association of Variable Star Observers in Cambridge, Massachusetts.

"Most of our work is done by amateur astronomers," said Janet Mattei, the association's director. "We exist because of them."

Every clear evening in communities across the country, AAVSO members track stars that vary in brightness, velocity and spectral type. Last year they contributed 250,000 observations. Because it wants amateurs to get involved, the AAVSO fits observing programs to a newcomer's location and ability, and even provides star-finder charts. Observers range in age from 10 to 80, but a person must be 16 to be a full-privileged member. Most importantly, said Mattei, "we need somebody with time on his or her hands."

Amateurs sometimes discover new comets, even though your chances are remote unless you live in a desert with clear, light-free skies. Still, the same rules apply for the backyard observer as for the PhD at a major observatory: whoever sends in the first telegram announcing a bona fide discovery to the International Astronomical Union gets the comet named after him or her.

Ever since the fifth grade, David Deskins wanted to catch one dim sky object: Comet Halley. But his home in Pikeville, Kentucky, is far from any major observatory. "I wanted to see that rascal," he recalls.

Twenty-something years ago, Deskins decided to educate himself about the universe. "There were no clubs, no one I could talk to at the local level," he says. "I was compelled to look up—and I started to see more."

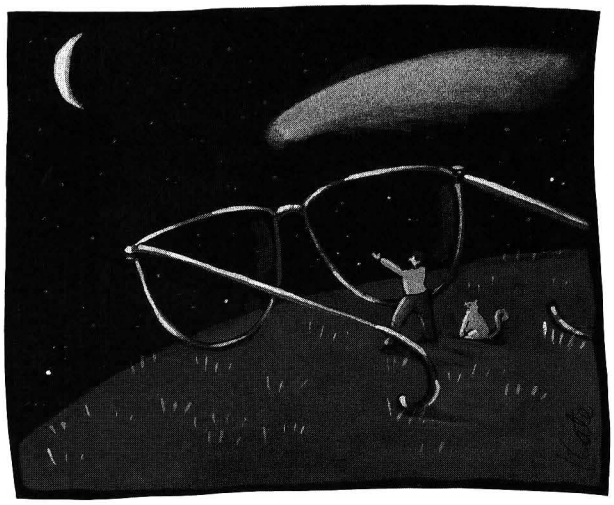
The cosmic love affair with the stars forced Deskins to lie about his age to get a construction site job. At age 15, he saved his money for a four-inch refracting telescope. Years after he began casually scanning the heavens, Comet Halley arrived above Kentucky. Deskins quickly realized he was the only man around who knew where the comet could be sighted, and he invited anyone who wanted to see it to come over and watch.

Halley's visit lasted several months, and the love affair paid off. Deskins collected hundreds of Halley photographs, all taken by amateurs from around the world. His book, *Looking Back: Amateur Adventures with Halley's Comet 1985-1986,* was published in 1987.

There's nothing to stop an amateur from enjoying the night sky, even when it's just for fun. One minor investment can help you dazzle your friends at summer lawn parties: a planisphere, also known as a star finder, which shows you the constellations at any given moment. Treat it like a bible. If you try to memorize every constellation you'll only frustrate yourself. Instead, look for one constellation every night for a week—you'll soon pick out the other sky stuff easily. That's when astronomy becomes fulfilling.

Although LeRoy Doggett of the Naval Observatory was surprised by how many people volunteered for Moonwatch last summer, he wasn't surprised to learn that most of them gained something from the experience.

"One lady in West Virginia drove to an observing spot while listening to Brahms in her car," Doggett says. "She told me she didn't see the Moon, but had a good time. We got a lot of people looking at the sky. I think that's terrific." □



KATE BRENNAN HALL

GET LOST IN SPACE

Night View—only stars glow

Day View
see names and constellations

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EARTHLY PURSUITS

Back In Time

Indiana Jones meets Buck Rogers

▼ ▼ ▼

By Vincent Kiernan

No one had seen the Mission Santa Fe de Toloco for nearly three centuries—not since marauding British soldiers had sacked and burned the place in 1702. But with the help of an airborne heat-sensing scanner developed by NASA, archaeologists in Florida recently were able to trace the hidden outlines of the mission's three main buildings by noting subtle differences in soil temperature in an empty pasture.

All in a day's work for the space-age archaeologist.

Time travel may be impossible, but remote sensing technology is helping a new generation of scientists do the next best thing: study past civilizations through the artifacts they left behind.

Special sensors aboard spacecraft, aircraft and balloons— and even some that are hand-held—are allowing archaeologists to make important discoveries that would be impossible with more traditional techniques.

"I think we are witnessing a revolution in archaeological research," says Farouk El-Baz, director of the Center for Remote Sensing at Boston University, which specializes in the new archaeological methods.

Every archaeologist faces the question of where's the best place to dig. In years past, expeditions made hit-and-miss decisions on where to excavate, based on the locations of previous discoveries or even just gut feelings. Remote sensing reduces some of the guesswork; images of a region taken from above can guide diggers to the most promising sites.

For example, the outlines of an ancient settlement often are invisible to a ground-based observer but clear from a high vantage point. Hills may indicate where items are buried, and even subtle changes in color can be important clues. As a result, says El-Baz, "You don't have to pock-mark the whole territory, as if it were hit by a thousand bombs" before you hit paydirt.

Remote-sensor archaeology even allows scientists to answer questions that traditional archaeology can't handle, such as how a civilization was distributed over a large area. "In some cases, there might be no need for digging at all," El-Baz points out.

As an example, he cites research by three Boston University archaeologists who studied the ancient Greek city of Corinth in 1986. Using a video multispectral camera carried 800 meters aloft by a blimp, the trio recorded nearly half a million images of the nearby seaport of Lechaeum, the Roman forum and Greek gymnasium, and the citadel of Arcocorinth. Even with preliminary computer processing of the images, the researchers have found hints of ground features that warrant a closer look.

El-Baz is no newcomer to the field of remote sensing. He served on NASA's panel for selecting sites for the Apollo lunar landings and for ten years directed the Center for Earth and Planetary Studies at the National Air and Space Museum. A former science advisor to Egypt's late president Anwar Sadat, El-Baz applied remote sensing to study that country's heritage in late 1987. At the Egyptian government's request, he organized a project to examine and photograph a 4,600-year-old funerary boat sealed in a limestone chamber.

KEVIN CARLETON/BOSTON UNIVERSITY

Pharoah's 4,600 year-old funeral barge

El-Baz calls the technique—which uses a special air lock, drills, and remote-controlled cameras—"video archaeology." He and the National Geographic Society now are discussing with the Chinese government the possibility of using similar systems to explore the tomb of a Chinese emperor.

Recently the Boston University center trained 16 mid-career archaeologists in the use of remote sensing. According to El-Baz, they have used their new-found knowledge at sites from Arkansas to southern France.

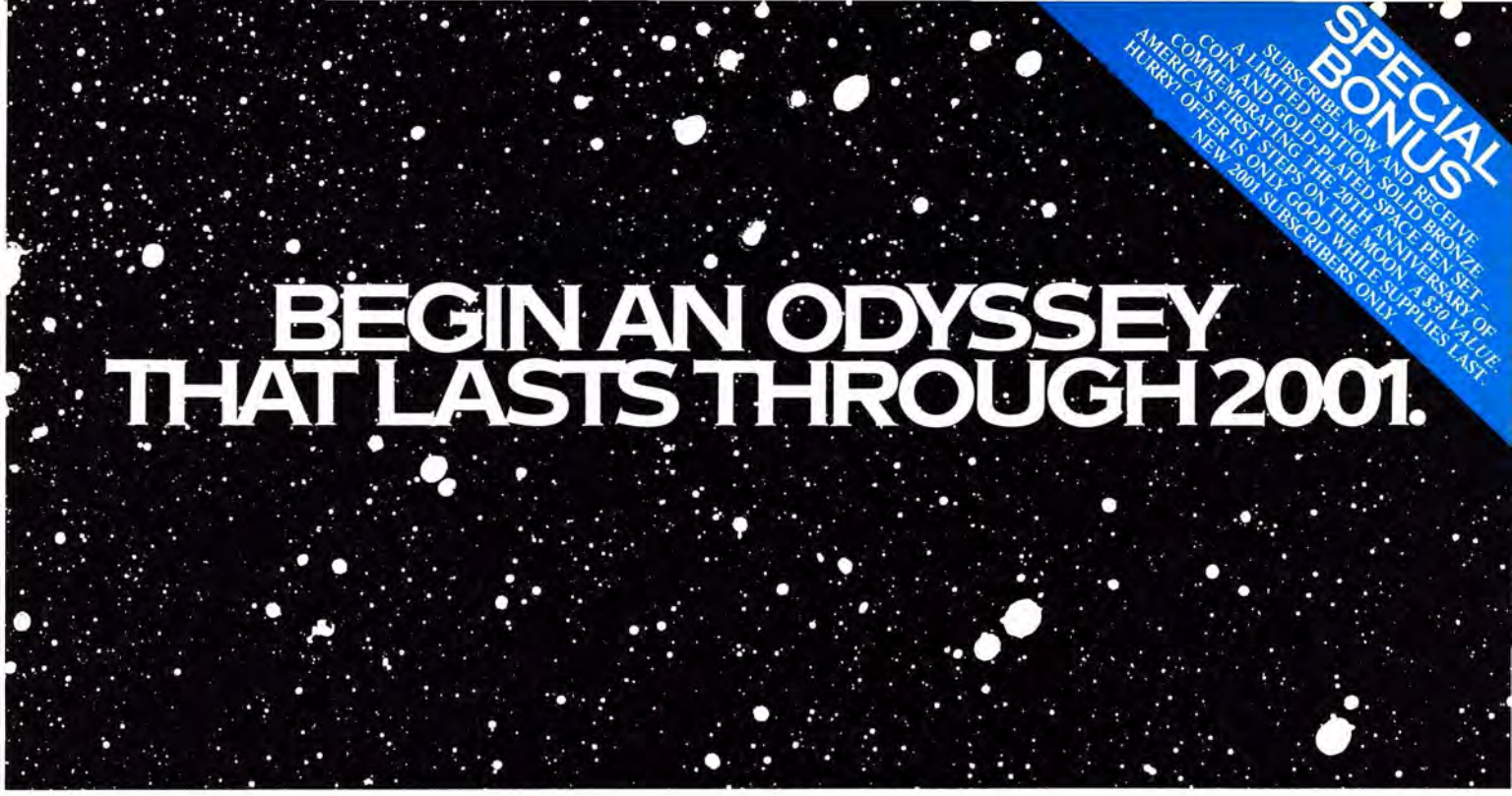
Not all archaeologists are enthusiastic: El-Baz still encounters skepticism and sometimes even outright opposition among older scientists. "Many archaeologists of yesteryear have not been trained with fancy instruments, are not computer whizzes. They don't even know how to handle a computer," he says.

And the science itself still is in its infancy. As an example, El-Baz notes that there are no guidelines on the best type of imagery to use for any particular archaeological application. The limited resolution of available imagery also poses a roadblock: Although spy satellites are reputed to be able to read license plates, the systems aboard civilian satellites are much less powerful.

"You're lucky if you get [a resolution of] 10 meters," El-Baz laments, adding that the Soviet Union has sold some imagery with six-meter resolution.

El-Baz is confident that future improvements in resolution will convince increasing numbers of archaeologists to join ranks with the geographers, geologists and other scientists who already recognize the value of remote sensing:

"Archaeologists are beginning to come to the fold and recognize that here is a tool that really can do *wonders* for them." □



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BOUNDARIES

The Case of the Missing Planet

Does "X" mark the spot?

▼ ▼ ▼

By Beatrice S. Smith

The case began on February 18, 1930, the day astronomer Clyde Tombaugh found Pluto, the ninth—and so far farthest—planet from the Sun.

Tombaugh discovered the tiny planet by searching an area which had been predicted by astronomer Percival Lowell back in the 19th century to be a likely spot for discovering a "new" world. By comparing two sets of photographs taken six days apart, Tombaugh could tell if any change had taken place in that particular section of sky.

Eureka! On that February afternoon, one little point of light "moved" as only a planet would appear to move. Clyde Tombaugh was overjoyed—at least for a while.

The search for a ninth planet had been motivated by known irregularities in the motions of Uranus, the seventh planet from the Sun. The discovery of Neptune, the next planet outward, explained in part why Uranus behaved as it did—but only in part. What's more, Neptune's orbit also was found to be perturbed. Astronomers figured there had to be another planet out there somewhere, a massive body with a powerful gravitational field.

But Pluto wasn't it.

The trouble with Pluto was its size. The new planet was only 1,370 miles across, and weighed only 15.6 billion billion tons—a large figure if you're talking carry-on luggage, but just a bit of dust on the cosmic scale, far too small to affect other planets' orbits. In fact, some astronomers questioned whether Pluto should be classified as a planet at all; perhaps, they said, it should be lumped together with the thousands of small rocky asteroids. Clyde Tombaugh didn't agree, and said so—vehemently. But even he admitted that Pluto was very small indeed, and that there had to be another "Planet X" out there somewhere.

Still, skeptics abound. After reviewing many types of orbital measurements, John Anderson of NASA's Jet Propulsion Laboratory has found no unexplained planetary perturbances dating back as far as 1910. Anderson also analyzed the motions of the twin spacecraft Pioneer 10 and 11 as they cruised the outer reaches of the Solar System. If a massive Planet X were following a typical solar orbit, it should have exerted a gravitational pull on the tiny free-floating twin spacecraft. In fact, said Anderson, even a *small* planet would tug at the Pioneers if it were close enough.

"I didn't expect Planet X to perturb the Pioneer spacecraft," counters Robert Harrington of the U.S. Naval Observatory in Washington. According to Harrington, who co-discovered Pluto's moon Charon in 1978, Planet X is small—only two to five times Earth's mass. He also has a ready explanation for why the Pioneers' paths stayed true: Both spacecraft stayed in the plane of the Solar System, but the orbit of Planet X is inclined 30 to 40 degrees. Harrington also claims the path of Planet X around the Sun is "eccentric," or much farther away at its greatest distance from the Sun than at its closest.

Curiously, Pluto also has an eccentric orbit. Neptune's large moon Triton circles in the opposite direction from most planetary satellites, and a smaller moon, Nereid, also takes an unusual path. All of this intrigued Harrington. In 1978 he and his colleagues revived an idea—first proposed in the 1930s—that Pluto, Triton and Nereid all were originally satellites of Neptune. When an unknown planet came uncomfortably close to Neptune, the intruder's gravity reversed the orbit of Triton, elongated the orbit of Nereid and booted Pluto from the system altogether.

MARGARET HUBER

After running computations to see what kind of body could have caused such havoc, Harrington found that the unknown planet had to have a mass two to five times that of Earth, and might now lie in an eccentric orbit—much the same as the proposed Planet X.

Another intriguing speculation, by University of Southwestern Louisiana astrophysicist Daniel Whitmire, has Planet X at one time passing through the ring of comets surrounding the Solar System. Comets pulled along by Planet X's gravity could have smashed into Earth, throwing enormous amounts of debris into the atmosphere that would block out sunlight. Plants would have died en masse, followed by the animals that depended on them for food. And that would tidy up the long-standing case of the disappearing dinosaurs.

"Nonsense!" says Brian Marsden of the Harvard-Smithsonian Center for Astrophysics. Marsden—a friend of Harrington's—thinks that other explanations, including observational or instrumental error, have to be considered before "jumping to wild conclusions" about mystery planets and the like.

But Harrington insists he's "better than 50 percent certain" Planet X exists, probably in the southern celestial hemisphere. He now has a team of astronomers in New Zealand taking photographs which they send back to Washington, where Harrington examines them for clues to the mystery of Planet X.

And he intends to keep searching until he finds the solution. □

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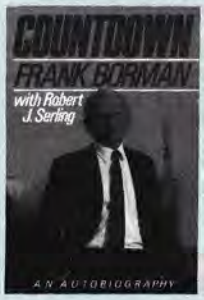

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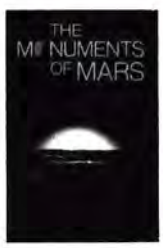

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GLOBAL CURRENTS

Other Voices

How Europe sees America's space program

▼ ▼ ▼

By Jean Paschke

Think of the international press corps covering a space shuttle launch, and you probably picture a polyglot assortment of reporters eagerly gathered at Florida's Kennedy Space Center, cameras and tape recorders at the ready.

In fact, many foreign press agencies don't have the personnel or budget for this type of reportage. They may drop in at the Cape or Houston occasionally, but they're more apt to talk with their American media counterparts or telephone their questions in to NASA. They read American newspapers, listen to the radio, or put their feet up and watch the Cable News Network coverage.

On television, says *London Times* correspondent Mohsin Ali, "You can see the close-ups and how people react. How many questions do you get to ask in a gang of reporters?" Ali targets his reports to the British lay person, trying to find a middle ground between technical jargon and oversimplification.

News of the U.S. space program is front-page stuff throughout most of Europe—on launch day, anyway. Follow-up stories are given lesser priority, but they still have an audience. One newsman who did visit Houston during last December's Atlantis mission was Ullrich Schiller, bureau chief of the West German Broadcasting Company's Channel 2. He dropped by just as a new shower for the NASA/international space station was being unveiled, and his piece on this latest technology was carried by almost all the stations in his satellite link.

"They hadn't heard about humanistic things in quite a while," he said of German audiences. "They want the most minuscule details of fact—stories on cross winds, what the astronauts eat."

Thomas Nehls, his colleague at Germany's Channel 1, thinks his main job is not to report on the nuts and bolts, but to convey a sense of what the American people think about space and other issues. He said that banners go up and news stories appear in West Germany on the anniversaries of American space events.

Agence France Presse correspondent Jean Vandoorne reports quite a bit of interest in space "when it's French rockets. There is more interest in the French astronaut [Jean-Loup Chretien] who was with the [Soviet] Mir crew." Vandoorne and his colleagues reported on the tenth anniversary of the orbiting of Venus by Pioneer 12, but he found the resumption of shuttle flights uninteresting, on the whole.

Nehls and Schiller both thought West Germany's reaction to Discovery's mission was the same as America's: a mixture of relief and the doubt that always lingers about piloted flight.

"I don't see any significant difference between here and Germany," said Schiller. "We really bent over backward to cover every aspect of it. I can't imagine more American coverage."

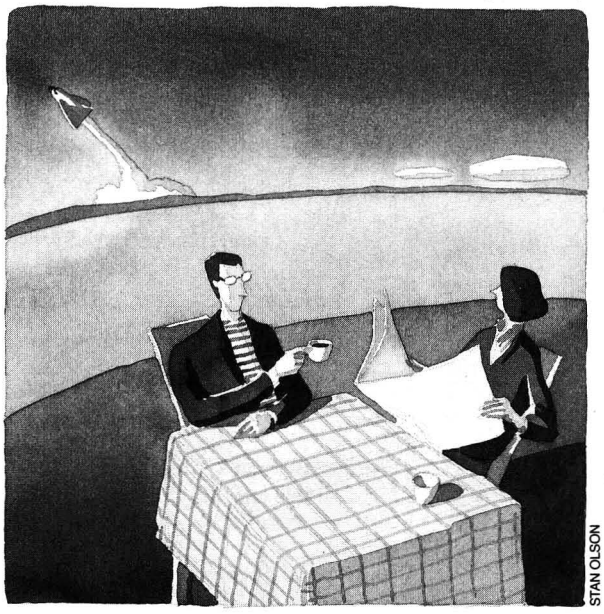
Mohsin Ali of the *London Times* thinks each flight is newsworthy, especially those shrouded in secrecy: "A spy satellite to monitor military movements. The lead writes itself," he says.

The leads certainly wrote themselves the day of the Challenger disaster. The reactions of horror, distress and sadness were the same everywhere, but there were subtle differences of opinion on what was newsworthy and what was not.

"There was nothing special about Christa McAuliffe here," said Schiller about West Germany. "She was just one of the crew."

"(My readers) don't remember she was a teacher," said Vandoorne. "They remember she was a woman."

"We had the same basic values and outlooks, the same human reaction that you had," said Ali of his British readers. "We had to consider what went wrong, how it will affect the U.S. space program and how far it will put the U.S. behind the Soviets." He found great significance in the fact that McAuliffe was a teacher, chosen especially to share the knowledge she gained from her flight. Ali thinks she had proper training, and that she wasn't merely filling a slot that should have been occupied by a "real" astronaut.



STAN OLSON

His countryman James Burke, who was chief BBC correspondent for the Apollo lunar landing missions, and who is probably best known for his PBS-BBC productions "Connections" and "The Day the Universe Changed," sharply disagrees:

"I believe that putting civilians on the shuttle was a mistake, because it enhanced the view that the shuttle was not an experimental vehicle. No astronaut I've ever met agreed with it. I mean, it was a PR job!"

"The spreading of education *is* a PR job," counters Ali. "How do you spread knowledge? All publicity isn't bad." □

THE GLASS LADY

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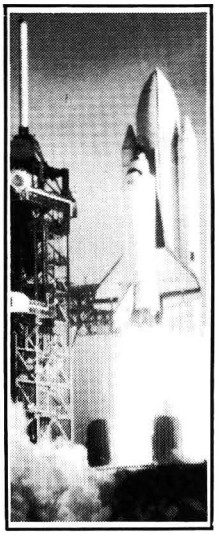

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Editor's Note:

An accidental, collector's book: THE GLASS LADY is about the space shuttle Challenger. Published six months before the Challenger explosion, the book is about flight onboard Challenger. When the first printing has been exhausted, the plates will be changed to avoid adding offense to tragedy.

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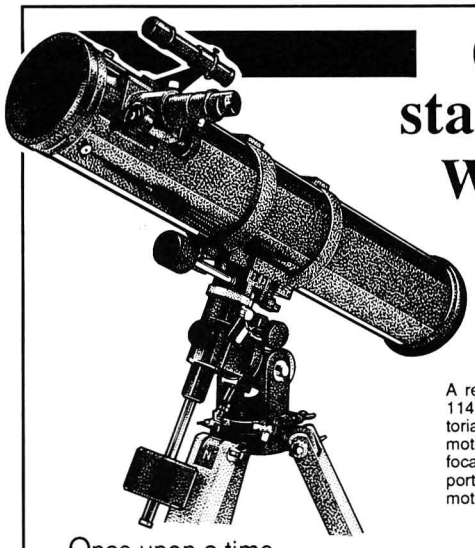

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REVIEWS

The Soviet Manned Space Program
by Phillip Clark
Orion Books
192 pages. $24.95

By William Barton

In a sense, the Soviet Union has had an "official," state-sanctioned space program since the founding of the Leningrad Gas Dynamics Laboratory in 1929. Others date the country's space efforts from that day in 1945 when Sergei Korolyov, the Soviet Union's answer to Wernher von Braun, was put in charge of the ballistic missile program.

In that context, it's astonishing how little Americans know about these space pioneers. This is partly due to Soviet secrecy, but also to our own inattention. More silliness has been written about the Soviet space program than any subject aside from UFOs.

This stylishly produced large-format book lays to rest many of the ill-founded rumors and theories about what the Russians have been up to in space for the last three decades. *The Soviet Manned Space Program* is filled with photographs and lavish illustrations covering all aspects of spaceflight, including cutaway diagrams of the major vehicles. The accompanying text discusses the evolution of the various Soviet programs in a way that's easy to follow, without talking down to the reader who may be encountering some of this information for the first time.

The British Interplanetary Society's Phillip Clark is an acknowledged authority on the Soviet space program. Coming as he does from the centuries-old British tradition of Russophilia, he avoids the condescending style of some American writers who treat the Soviet program in a derogatory way, focusing only on problems and errors. The book also has none of the anti-Americanism that occasionally taints the work of some British writers. When he makes comparisons between U.S. and Russian efforts, they are fair and impartial.

Clark traces the evolution of flight programs in a revealing way, showing not only what the Soviets actually did, but also what they *intended* to do. For example, the Voskhod program (the follow-on to the Soviets' first piloted craft, Vostok) consisted only of one three-man "stunt" flight and Alexei Leonov's brief space walk in 1965. But Clark writes that Voskhod originally was to have included a much longer flight, a manned biosatellite, a spacewalk by a woman and, incredibly, a journalist-in-space program that was not canceled until after Sergei Korolyov died in 1966. If Earthly politics had not intervened, the Soviet program of the 1960s would have seemed much more impressive.

The book perpetuates very few of the old guesses that used to be taken as gospel regarding the Soviet space program. In a final speculative chapter, where he discusses how the Soviets might have gone to the Moon in 1970—and how they might try again in the 1990s—Clark gives us a drawing of the failed Moon rocket that seems clearly derived from the old "megapound module" concept. It's curious that the design still has wide acceptance today, since a similar theory about the Soviets' Proton launcher proved ludicrously wrong.

The Soviet Manned Space Program will give the reader a solid grounding in the basics of Soviet space technology, and is a valuable addition to any international space library. □

William Barton is a science fiction author and long-time observer of Soviet space efforts. He currently is working on a novel about Soviet attempts to capture asteroids for space industrialization.

All the books written about the Soviet space program over the years probably would need an "Energiya" booster to lift them into orbit. Nevertheless, there are several good overall reference works which should be part of your Soviet space bookshelf:

Race into Space: The Soviet Space Programme (John Wiley & Sons, 1988) by Brian Harvey, is a broad survey of Soviet space efforts from the days of Konstantin Tsiolkovsky up to the present and future. The author has to cover a lot of ground in 370 pages; don't expect an exhaustive treatment of any particular subject. The book lacks color photos, and Harvey's prosaic writing style gets a bit taxing, but he does a credible job of touching all the bases.

Red Star in Orbit (Random House, 1981) and *The New Race for Space* (Stackpole Books, 1984), by James E. Oberg. Oberg has a free-swinging, anecdotal style that will appeal to most readers. Besides plenty of good information, you'll probably get a feel for Soviet space thinking not found in other, more academic works.

The Soviet Cosmonaut Team (GRH Publications, 1986), by Gordon R. Hooper, is a compendium of biographical sketches on every Soviet and Intercosmos spacefarer from A (Aksyonov) to Z (Zudov). The sections on cosmonaut selection and crew assignments are a bonus.

Soviet Space Programs, 1981-1987, Vol. 1 (Government Printing Office, 1988). This U.S. government account of Moscow's space program is the latest in a series of Congressional Research Service reports dating back to 1962. It probably packs more facts per page than most popular books. Check with the GPO for availability of earlier volumes.

Finally, Imported Publications of Chicago offers a number of Soviet space books in English translation. Current titles include *Space Flights Serve Life on Earth*, by Alexander Koval and Lev Desinov, and *Into Space*, a child's pop-up book by cosmonaut Vitaly Sevastyanov. The toll-free number is 800-345-2665.

□

Spaceplanes

continued from page 39

plans for the early 21st century as early as 1987. Very soon, the Mitsubishi company was working on LACE, the most important of the new technologies and the hardest to develop.

During the 1990s, Japanese companies were increasingly active in laying the groundwork for a future spaceplane. The project was formally under way by 1997, and in 2006 the first prototype flew to orbit. With this success, the Japanese could claim to be a spacefaring power on a par with any other in the world.

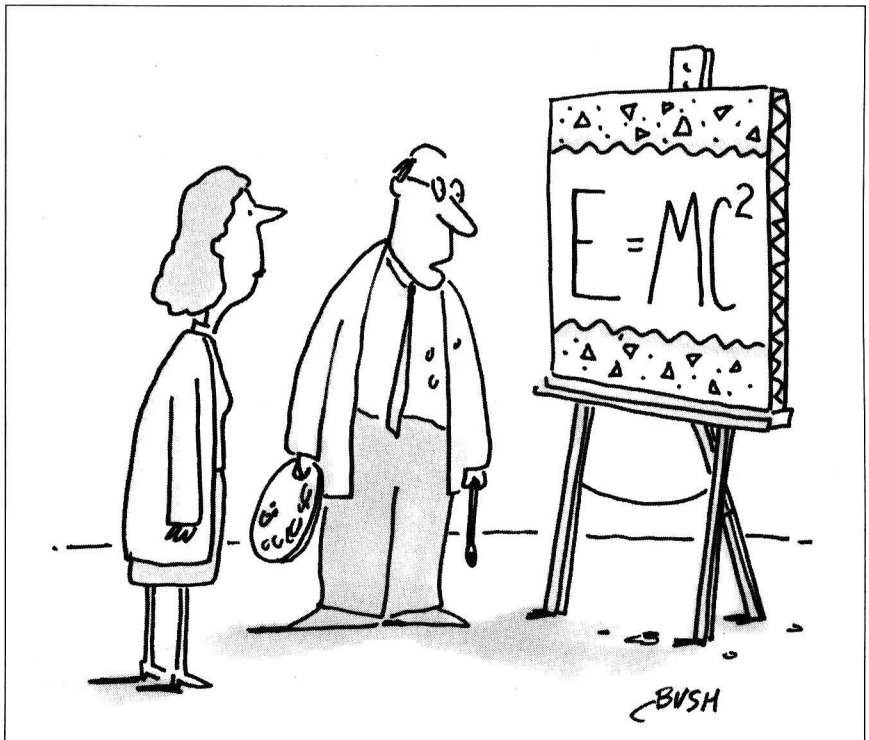
American efforts stemmed from the early National Aerospace Plane program, which ran from 1986 to 1996. This Air Force and NASA project designed and built the experimental X-30 spaceplane—the world's first—which hustled into orbit on scramjets in September 1996. But the X-30 was purely a research craft, and carried no useful payload. America's *real* spaceplane operations with a cargo-carrying craft didn't begin until 2003. That kept the Americans ahead of the fast-charging Japanese, but only barely.

Europe's Saenger has a similarly lengthy pedigree. Late in the 1980s France's aerospace industry got the jump on Germany by building both the Ariane 5 heavy-lift rocket and the Hermes mini-shuttle for the European Space Agency. Executives at Messerschmitt-Boelkow-Blohm, West Germany's largest aerospace company, were determined that the *next* major space effort by the European Community would be in response to their own design. MBB convinced the German government in Bonn to kick in enough money for an initial five-year program of studies, running through 1992. That led to a subsequent eight-year effort, which built an experimental version of Saenger's hypersonic first stage.

When the Ariane 5/Hermes development effort ended around 2000, the Germans were next on the runway. They readily won full European backing for the two-stage Saenger, mollifying the French by using a great deal of Hermes technology in the Saenger second stage. Eight years and $20 billion later, Saenger was in full operation.

As a bonus, that same Saenger first stage, suitably modified, now carries paying passengers on commercial flights across the Pacific and between the world's major cities. In essence, the designers simply removed one of the main hydrogen fuel tanks and replaced it with a cabin for 230 people. This changeover worked rather easily, thanks to serendipity: Passengers have about the same density—five pounds per cubic foot—as liquid hydrogen.

Several hundred of these sleek black airliners are now in service, their vast delta-shaped wings and twin vertical tails making them look as if they could break the sound barrier just sitting on the ground. With a range of 7,000 miles



I consider it more of an art than a science.

and a speed of Mach 4.4, they turn the old grueling fifteen-hour trans-Pacific flight into a smooth three-hour hop.

Even a flight into orbit now has the same sense of routine. The explorers are elsewhere: at the lunar base, or preparing for the next international mission to Mars. But in Earth orbit, astronautics is off the front pages and on the business pages, along with other "gee-whiz" technologies of yesteryear, superconductors and genetic agriculture.

Space near the Earth, in 2015, is merely an upward extension of the atmosphere. Advanced designers are already planning the next generation of spaceplanes, which they hope will be inexpensive enough to permit tourists to fly to the world's first orbiting hotel.

If the last ten years or so is any guide, it's not too early to start planning your reservations.... □

T.A. Heppenheimer is a frequent contributor to Final Frontier *and the author of* The National Aerospace Plane, *published by Pasha Publications.*

Artificial Gravity

continued from page 30

Whether I'd happily do it again on the thousand and one nights of a mission to Mars is another question. For one thing, flat on the back with hands at sides is not a comfortable posture for most humans who are still breathing. For another, to conserve space, several beds would probably be arranged spoke-like around a hub of rotation. Who could sleep head-to-head-to-head like so many fishsticks on a microwave-safe plate?

Back in Washington, Lemke has a hunch that the best artificial gravity system for a long, stressful flight is the one that minimizes Coriolis effects and most closely duplicates Earth's—a long radius, with a slow rate of rotation. He tinkers at blackboard and computer with the possibility of two craft joined by a flexible tether the length of five football fields. Questions buzz. How to control them? How to slow the system down? Only two things are certain. It will be at least a decade before we get the ideas all ironed out. And when we do, we're guaranteed to have a solution that would make old Isaac Newton's head spin. □

C. J. Houtchens is a slightly dizzy Washington D.C.-based freelance writer who may never ride the merry-go-round again. Her last piece for Final Frontier *was a profile of jazz saxophonist Jane Ira Bloom.*

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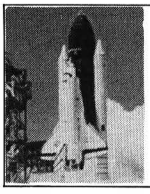

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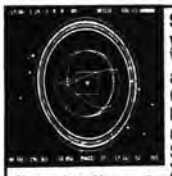

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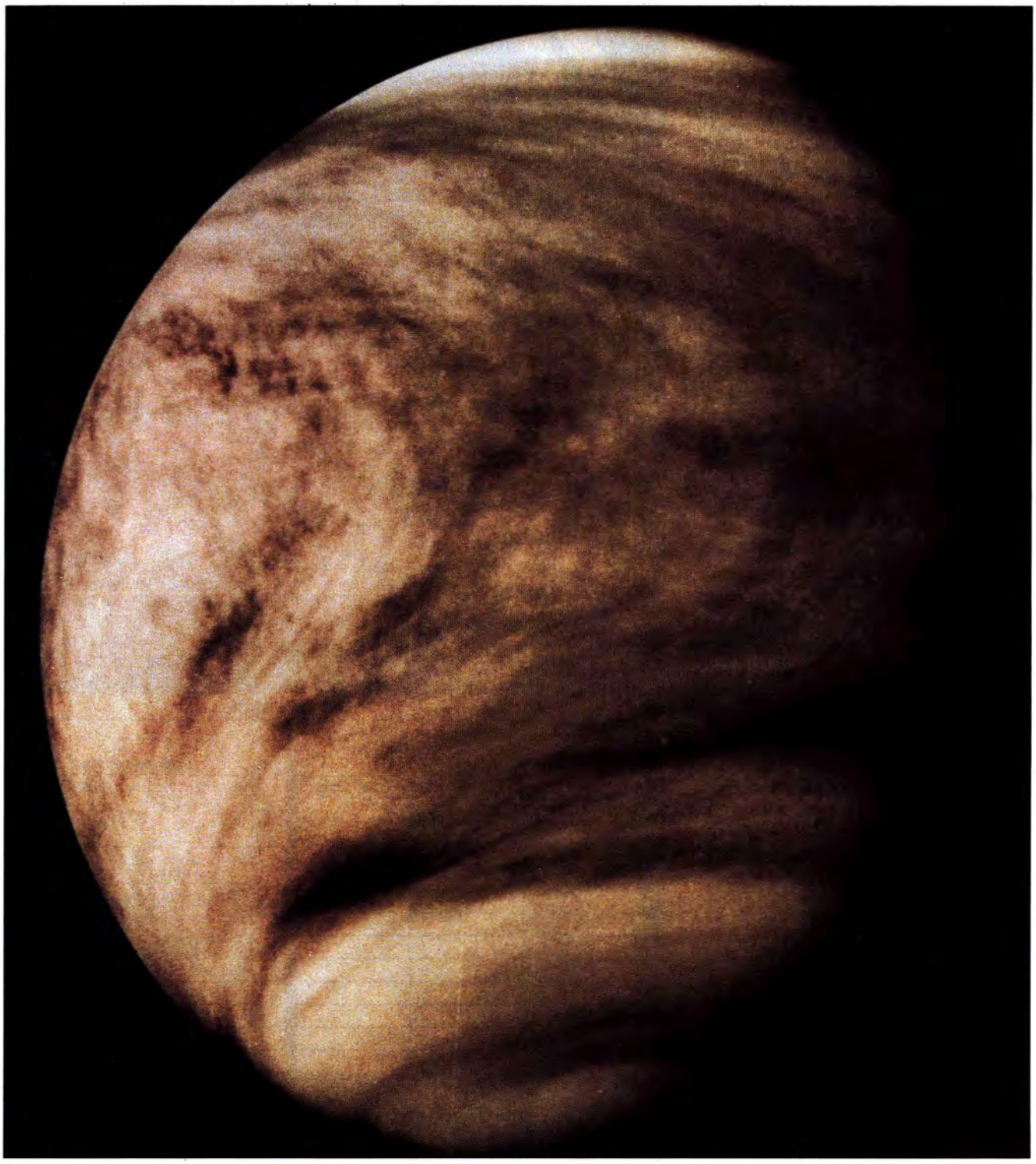

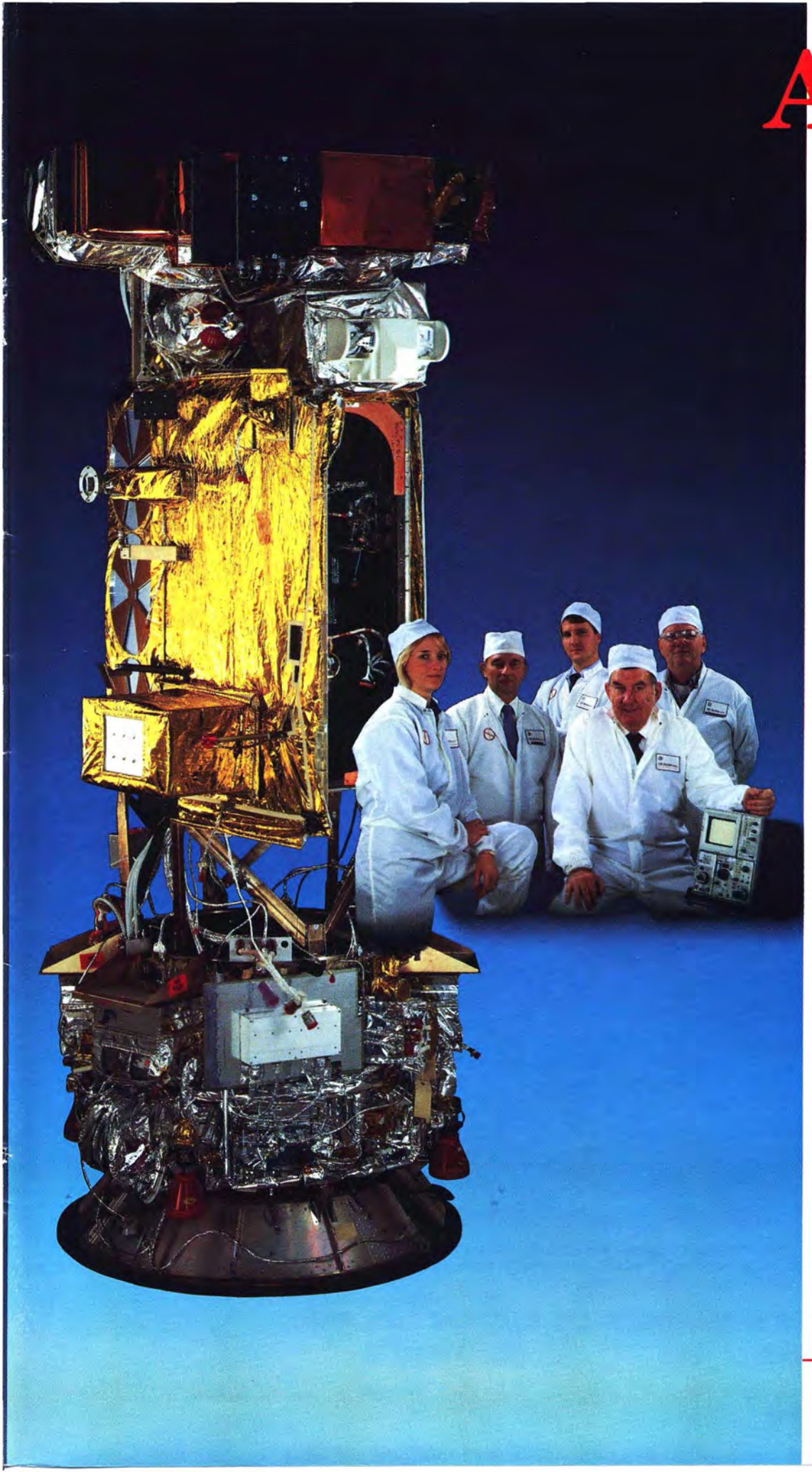

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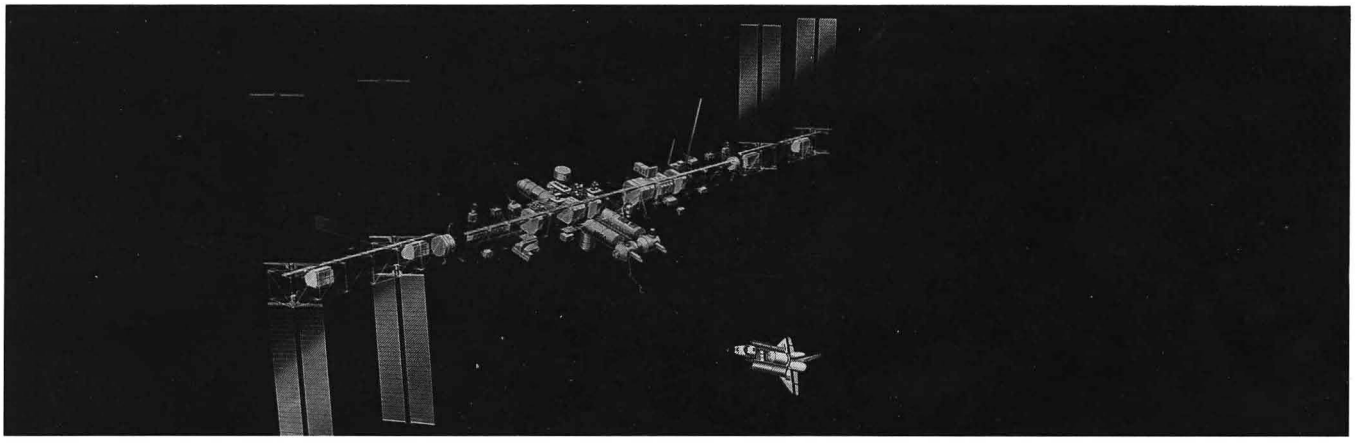

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